Fractures of the acetabulum

Heeg, Minne

FRACTURES OF THE ACETABULUM

M. HEEG

FRACTURES OF THE ACETABULUM

STELLINGEN

1. Bij ieder kind met een bekkenfractuur dient systematisch te worden gezocht naar retroperitoneale letsels.

2. Bij acetabulumfracturen bepaalt de ernst van de kraakbeenschade in belangrijke mate de prognose.

3. Centrale luxatiefracturen van de heup bij patienten met preëxistente degeneratieve afwijkingen dienen conservatief behandeld te worden.

4. Ter preventie van ectopische botvorming na operatieve behandeling van acetabulumfracturen dient behandeling middels lage dosis radiotherapie te worden overwogen.

5. De behandeling van gastro-oesophageale reflux middels implantatie van de Angelchik prothese is doeltreffend en betrouwbaar.

6. Echografie kan een belangrijk diagnostisch middel zijn voor aandoeningen van het steun- en bewegingsapparaat, mits de behandelend arts dergelijk onderzoek zelf uitvoert.

7. De vernietiging van 10 jaar oude röntgenfoto's, zoals thans gangbaar is, zal het patient gebonden onderzoek in de Orthopaedie ernstig belemmeren.

8. Het is een omineus teken als de chirurg zijn patient alleen van de röntgenfoto herkent.

9. De oplossing voor de dioxineverontreiniging van mens, melk en milieu ligt niet in het sluiten of verbeteren van de verbrandingsinstallaties maar in het opleggen van dwingende maatregelen ter beperking van het PVC verbruik.

10. Het feit dat een groot deel van de bevolking de VUT-regeling financiert zonder daar zelf een beroep op te kunnen doen dient als sociaal onrecht te worden beschouwd.

11. Hereniging van de beide Duitslanden vergroot de medaille-kansen van sporters uit andere landen.

Stellingen behorende bij het proefschrift
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Promotores : Prof. Dr. H.J. Klasen
Prof. Dr. H.K.L. Nielsen
Referent : Dr. J.D. Visser

Promotie-commissie: Prof. Dr. J.W.F. Beks
Prof. Drs. B. Binnendijk
Prof. Dr. C.J.P. Thijn

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Contents

Chapter 1

General introduction and aims of the studies

GENERAL INTRODUCTION

Fractures of the acetabulum were described long before the discovery of X-rays. The first rather vague description of an acetabular fracture can probably be attributed to Ambroise Paré (1510-1590) when he described patients with an unstable posterior fracture-dislocation of the hip [1]. As to the prognosis of a dislocated hip he commented in 1575:

> "There is this danger in the dislocation of the hip that either the bone cannot be put into place again, at least unless with much trouble, or else being put in that it will presently fall out again."

It is very likely that several of these patients were suffering from a fracture of the posterior wall of the acetabulum, although Paré did not describe it as such.

Sir Astley Cooper (1768-1841) described a similar patient in 1823 [2]. The fracture and extent of injury were diagnosed post-mortem. Cooper commented:

> "In cases where the acetabulum has been fractured, although the head of the femur has been readily replaced, I have seen it impossible to retain it in its proper position. This difficulty, I apprehend will depend upon the size of the portion of the acetabulum which is separated."

With this statement, he clearly described one of the limitations of conservative treatment of unstable acetabular fractures. It took more than a century before open reduction and internal fixation could solve the problem of redislocation. These and other early reports on acetabular fractures in the nineteenth century were mainly concerned with three major problems: the symptoms and diagnosis; the manipulations required to reduce the posterior or central dislocation; and redislocation of the hip [3-6]. The management of these fractures after reduction and the prognosis were barely discussed.

With the introduction of radiography in 1895, interest in acetabular fractures was renewed, as many surgeons were impressed by the radiographic presentation. Hoffa reported an increased incidence of acetabular fractures at the turn of the nineteenth century, which he related to a growing number of traffic and industrial accidents [7]. Despite the growing incidence, only 55 central acetabular fractures could be collected from world literature in 1912 [8].

Surgeons became actively involved in the mechanics of producing acetabular fractures. Schroeder, for instance, reported his experimental work on cadavers in 1909 [9]. He was able to produce central acetabular fractures by striking a lateral blow to the greater trochanter. By striking the knee with a hammer he tried to produce posterior wall fractures, but did not succeed, as this resulted only in femoral neck fractures. On the basis of his experiments, he concluded that a direct force applied suddenly to the pelvis resulted mainly in central acetabular fractures.

By now, a division had grown between the posterior and central types of acetabular fracture. Posterior fractures were considered to be an extension of pure posterior dislocations and were classified as such [10-15]. Central acetabular fractures, however, were less easy to classify. The first to attempt such a classification was Skillern (1912), who divided fractures into "Fractura Acetabuli Perforans" and "Fractura Acetabuli Perforata", depending on the degree of central protrusion of the femoral head [8]. As more and more surgeons became aware of the "peculiar characteristics" (Palmer, 1921 [16]) of

Fig. 1. Reduction of a posterior fracture dislocation of the hip as illustrated by Brocq and Chabrut (1936). The patient lies supine and the pelvis is stabilized by an assistant. Traction is applied, maneuvring the hip to 90 degrees of flexion. The hip is gently rotated internally and externally until reduction is achieved.

central acetabular fractures, numerous other classifications followed, many of which were impractical [16-19].

A variety of usually successful methods were available to reduce posterior fracture-dislocations (Fig. 1). An excellent historical review of the methods used in Europe was presented by Stemshorn [20].

The difficulties encountered in disengaging the femoral head from the pelvis in central acetabular fractures were far greater. One of the more popular techniques was described by Whitman in 1920, in which the greater trochanter was used as a fulcrum, to distract the femoral head [21]. This technique remained popular for many years [22-24]. The importance of capsular and ligamentous structures around the hip in aiding manipulative reduction was recognized by Levine [25]. Later, Elliott [26] pointed out that because of a lack of these specific capsular attachments to the medial acetabular wall, reduction of these displaced fragments was difficult to accomplish with closed reduction and manipulation alone. Others, therefore, recommended manipulation through the rectum, to facilitate reduction in central acetabular fractures [27].

Once reduction of either the posterior or central dislocation had been obtained, further treatment was conservative in most cases and consisted of

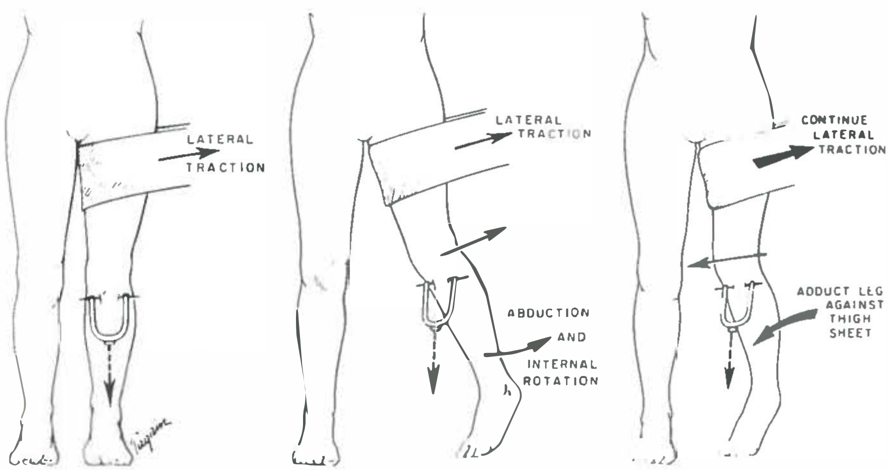

Fig. 2. Closed reduction of a central acetabular fracture as designed by Rowe. Axial traction is applied to the affected leg through a Kirschner wire inserted in the proximal tibia. Lateral traction is maintained through a swathe high in the groin, held by an assistant. The leg is flexed, abducted, rotated internally and externally and eventually circumducted in a neutral position. By doing so, traction is applied to the short rotators of the hip with the purpose of molding the fragments.
(Reproduced with permission after: Lowell JD. Bursting fractures of the acetabulum, involving the inner wall and superior dome. A.A.O.S Instructional Course Lectures 1973;22:145-158).

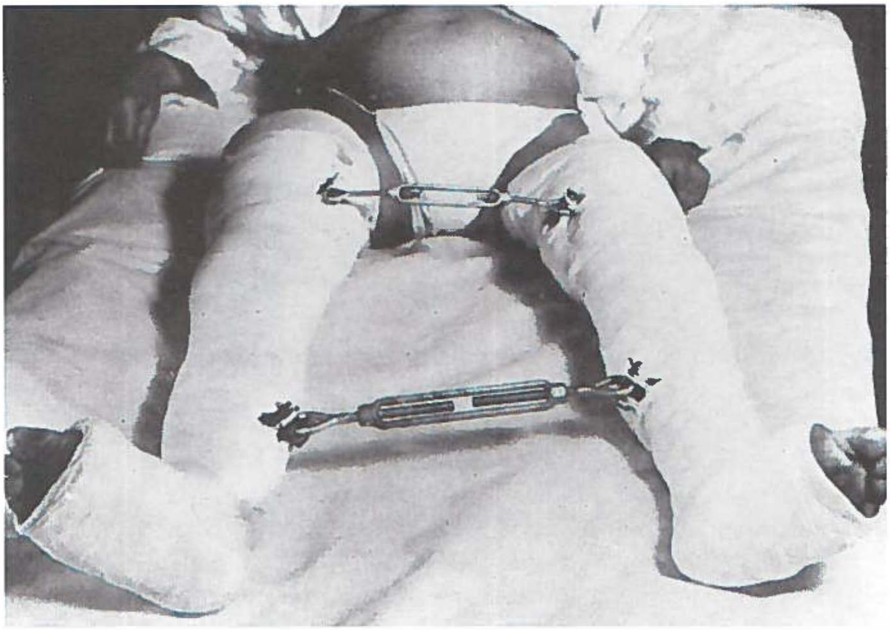

Fig. 3. The Jahss turnbuckle cast, used for the treatment of pelvic and acetabular fractures with central dislocation of the femoral head. The patient has two long-leg casts connected by turnbuckles. Using the lever principle, by applying medial compression or lateral distraction, reduction of fracures could be obtained, without general anaesthesia.

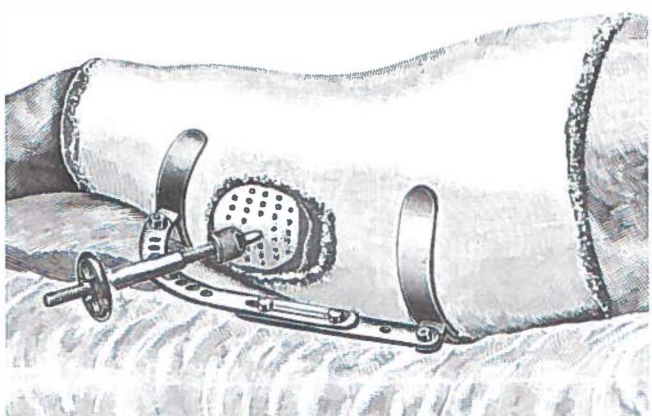

Fig. 4. The windowed hip spica designed by Leveuf (1932) to reduce central acetabular fractures. The apparatus exists of a plaster of paris cast applied from pelvis to knee with a window at the trochanter level. A wood screw is inserted in the trochanter, connected with a traction device at the lateral aspect of the cast. Leveuf advocated cautious reduction of fractures by increasing the traction once in a few days. The apparatus stayed in place for 60 days.

cast immobilization from toes to costal margin or traction. A variety of traction techniques were invented; especially for the central types of fractures: slings and pressure pads applied to the medial aspect of the thigh [16,27-29] (Fig. 2); the Jahss turnbuckle cast [30] (Fig. 3); Thomas Jones abduction frame [31] and windowed "hip spicas" [32] (Fig. 4).

Although many authors advocated some sort of lateral traction in central acetabular fracture reduction, it was not until 1926 that skeletal traction through the greater trochanter with a Steinman pin was reported [33], which meant that a better grip could be obtained on the proximal femur. With a number of modifications, lateral skeletal traction in combination with longitudinal traction became increasingly popular and remained so to date [34-38].

The detrimental effects of prolonged immobilisation in a hip spica were already recognised by Skillern in 1912 [8], but alternative methods were not available until the first reports appeared on operative treatment. Vaughan (1912) documented a case of a central acetabular fracture reduced via an anterior approach; he did not use internal fixation [39]. Lambotte (Fig. 5), the famous surgeon from Antwerp, published his "Chirurgie opératoire des fractures" in 1913 [40]. In this classic, he proposed a new fracture classification and reported on several cases of central acetabular fracture which were treated operatively, the first as early as in 1905. Lambotte also advocated an anterior approach, using a specially designed distraction hook, placed above the lesser trochanter, to distract the femoral head out of the fracture. Combined with longitudinal traction, 'distraction was no more than a game'. If redislocation occurred after traction had been discontinued, he proposed operative reduction of fragments. He did not describe which fixation techniques he used in such circumstances. Very likely, Lambotte employed screw fixation, which he used for all kinds of pelvic fractures.

Unfortunately, the work by Lambotte did not receive the attention which it deserved. Apart from these and other incidental German reports on operative treatment [41-43], conservative treatment remained the treatment of choice for most surgeons, untill reports appeared on open reduction with internal fixation in the Anglo-American literature. Diggle (1940)[44], using screw fixation and Levine (1943)[25], using plate and screw fixation, reported improved results for central acetabular fractures. They approached the fractures through a suprapubic, or Smith Petersen incision, respectively. Shortly after World War II, Urist reported the results of operative treatment of fractures which had occurred in jeep accidents [45,46]. He concluded that fractures which had destroyed a significant portion of the superior and posterior acetabular wall, required open reduction. The comminuted or protrusion type of central acetabular fracture had a poor prognosis and did not respond to any form of operative treatment and should be treated

Fig. 5. Albin Lambotte (1866-1955), was a surgeon with specific interest in the treatment of fractures. He worked his professional life in the hospital of Stuyvenberg (Antwerp). Here he developed his outstanding ideas, equipment and techniques for internal and external fixation of fractures. Apart from his medical skills, he was a talented sculptor, lute maker, musician and fisherman.

conservatively. Fractures limited to the anterior portion of the articular surface required no operative treatment as these fracture types had a very favourable prognosis after conservative treatment. He realized that a better system of classification and evaluation was necessary. Urist stressed the need for further study on the prognosis of these fractures in general and the true incidence of degenerative changes.

In the ensuing years, several authors published long-term follow-up studies on acetabular fractures [47-56]. Among these were the classic studies by Thompson and Epstein (1951)[48] and Waller (1955)[50]; both on the posterior type of fractures and by Rowe and Lowell (1961)[52] on both posterior and central acetabular fractures. In general, it was felt that the long-term results of posterior fracture-dislocations of the hip were directly related to the extent of the initial trauma [57-62]. The majority of authors recommended gentle closed reduction of the dislocation under general anaesthesia, as soon as possible but at least within 24 hours, in order to reduce the risk of avascular necrosis of the femoral head [14,53,63-67]. The incidence of avascular necrosis has been directly related to the length of time the hip remains dislocated. Weigand and Schweikert [68,69] noticed avascular necrosis in only 9% of their patients when primary reduction was performed less than six hours after the injury. This incidence increased to an astonishing 93% of the patients when reduction was delayed for more than six hours.

In addition, multiple attempts at closed reduction are contraindicated [70, 71].

Epstein launched a new philosophy, recommending primary open reduction of all posterior fracture-dislocations [72]. As he found loose fragments of bone and cartilage in 91% of the hip joints at arthrotomy, he believed that the removal of this debris with stabilisation of the posterior wall fragment would delay and minimize degenerative changes of the hip.

Regardless of the disagreement between primary open and closed reduction as the treatment of choice, the following conditions were considered by most authors to be definite indications for open reduction [73-84]:

1) failed closed reduction,
2) an unstable joint after closed reduction of the hip,
3) radiographically demonstrated loose intra-articular fragments or interpositioning,
4) sciatic nerve injury associated with a displaced bony fragment.

The preferred treatment for central acetabular fractures remained much more open to debate, although the emphasis shifted in the late 1950s and 1960s toward open reduction and internal fixation. Several authors reported their results of open reduction using various internal fixation methods: screws [85-90], Knowles' and Hagie pins [91,92] and plates [93,94]. As experience was limited, conclusions could hardly be drawn. The early literature on this subject is very confusing because broad generalizations were often made by grouping completely different types of acetabular fractures together.

Knight and Smith (1958)[91] realized that fracture classifications needed drastic improvement if results were to be compared. They described a practical working classification of central acetabular fractures by considering the acetabulum, when viewed from the front, as the face of a clock, dividing the acetabulum into quadrants. The restoration of the weight-bearing dome, although ill defined, was believed to be very important by these and other authors [52,88,94].

Knowledge regarding surgical anatomy and approaches [95-102] as well as reduction and fixation techniques [103-111] expanded. The most significant

Fig. 6. Prof. Emile Letournel.

contribution to the operative treatment of acetabular fractures and the understanding of these fractures in general came from Judet and Letournel. They profited from the extensive experience of other French surgeons in the field of acetabular fracture treatment, such as Cauchoix and Truchet [112], Creyssel and Schnepp [113]; Merle d'Aubigné and Mazas [78,89,114]. This 'French school' gave the definitive impulse for the operative treatment of acetabular fractures. The work by Judet and Letournel must be considered as a major breakthrough [115-124] (Fig. 6). They developed a classification system that was based on anatomical landmarks. The acetabulum was described very schematically as being contained within an asymmetrical inverted 'Y'. This asymmetrical bony arch is formed by the long anterior (or iliopubic) column and a smaller posterior (or ilioischial) column. Both columns are joined at their inferior ends by a tie beam, the pubic segment (Fig. 7). With this classification, the artificial division between posterior and central fracture types dissolved. Since its introduction in the early 1960s, this classification has been widely accepted. With the aid of three standard radiographs, the radiographic landmarks and the extent of skeletal injury can be determined accurately, as will be described in Chapter 3. The classification made a correlation between the fracture type and the most appropriate surgical approach, enabling the surgeon to make an optimal preoperative plan. Judet and Letournel believed that failure of nonoperative treatment was not due to poor reduction of the femoral head, but to the inability to reduce and hold the acetabular fragments. Therefore they recommended open reduction and internal fixation for every displaced acetabular fracture [125]. They applied the basic principles of treatment for displaced fractures (anatomical reduction, stable internal fixation and early motion) also to acetabular fractures. This line of thought was supported by the "Arbeitsgemeinschaft für Osteosynthesefragen" [126].

Despite the fact that the rate of operative complications, such as heterotopic bone formation [127], infection, sciatic nerve damage and vascular injury [128] was reported to be as high as 28% in Letournel's series [125], operative treatment became increasingly popular in the ensuing years [129-147].

Contrary to this view, however, many other surgeons felt that residual displacement of central acetabular fractures did not necessarily imply poor results and open reduction with internal fixation was not always justified [148-158]. This idea was strenghtened by the introduction of the so-called central dislocation operation by Charnley for the treatment of degenerative changes of the hip [159-161].

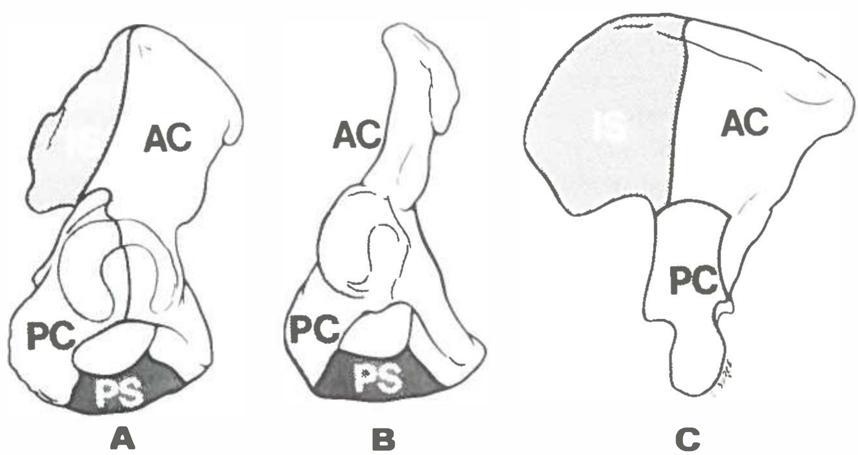

Fig. 7. The columns of the acetabulum as seen from the lateral (A), obturator oblique (B) and posterior projection (C).
[AC=anterior column; PC=posterior column; IS=iliac segment; PS=pubic tie-beam segment].
(Reproduced with permission after: Goulet JA, Bray TJ. Complex acetabular fractures. Clin Orthop 1989;240:9-20).

The effect of operative treatment on the development of avascular necrosis of the femoral head and degenerative changes remains a central issue in the discussion of operative versus nonoperative treatment. Compression and disruption of the vascular system [162-166] as well as mechanical compression of the femoral head [167-169] have been held responsible for the development of avascular necrosis. Elliott [26] and Urist [45,46] pointed out that no matter what the origin of this severe complication is, both the femoral head and the acetabulum sustain damage, even in the case of non-displaced fractures. They pointed out that the integrity of the acetabulum as a whole determines the result. Gay investigated ten femoral heads of deceased polytrauma victims after a fracture of the acetabulum [169]. Both macro and microscopical cartilage destruction and early-stage repair were always present. In a series of 92 acetabular fractures treated operatively, similar osteocartilaginous damage could be visualized on routine CT scans, but were not seen intra-operatively or on routine X-rays. These investigations indicate that extensive cartilage damage to the femoral head and acetabulum are indeed frequently present.

There are no conclusive findings as to whether or not these severe complications can be minimized with operative treatment, although this has been suggested frequently [143,144,170-173]. The prognosis and complication rate varies in different reports, which makes evaluation and comparison difficult. Furthermore, the variable prognosis is probably a reflection of the highly variable characteristics of the fracture itself. As a result of this and the unsatisfactory results of both conservative and operative treatment, primary cup arthroplasty [66,174,175], total hip replacement [176,177] and arthrodesis [48] has been introduced as a third treatment option for selected cases.

The choice of a specific type of treatment often depends on the general condition of the patient. As most injuries are caused by high-energy traffic accidents, many patients suffer from life- threatening disorders such as severe blood loss, thoracic, neurological, genito-urinary, gynaecological, or bowel injuries [178-185]. These associated injuries often dictate the initial management and may influence the decision as to whether or not to operate on the fracture. This important observation was made as early as in 1914 by Helferich [10] and is still valid today. Due to the high incidence of associated injuries, the mortality rate associated with pelvic fractures ranges from 5 to 20% [186,187]. This can primarily be attributed to the ineffective control of haemorrhage and the inability to prevent and control sepsis [188,189].

Although the management of these life-threatening injuries forms an essential part of treatment and often takes priority over the management of the fracture, it is not discussed here as it is beyond the scope of this thesis [190-194].

AIMS OF THE STUDIES

The advances made with regard to surgical techniques now enable surgeons to restore displaced acetabular fractures. Therefore emphasis should be focused towards the further differentiation of fractures which can best be treated by open reduction and internal fixation and those best suited to conservative management.

This retrospective study was undertaken to evaluate the long- term results of acetabular fracture treatment, in order to specify this differentiation. The following issues were therefore investigated:

- The radiographic evaluation of the acetabulum (Chapter 2).
- The classification of acetabular fractures, in children as well as in adults (Chapter 3).
- The results of operative and conservative treatment of acetabular fractures in children and adolescents (Chapter 4).
- The radiographic presentation, treatment and prognosis of physeal plate injuries of the acetabulum (Chapter 5).
- The results of conservative treatment of acetabular fractures in adults, in particular if congruency can be achieved in the weight-bearing dome (Chapter 6).
- The results and complications of open reduction and internal fixation of acetabular fractures in adults (Chapter 7).

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Chapter 2

Anatomy and radiographic assessment of the acetabulum

In this chapter, the essential skeletal characteristics of the acetabulum are described, followed by a survey of the radiographical techniques available to evaluate the injured acetabulum.

ANATOMY

The acetabulum is part of the innominate or hip bone, which is large and irregularly shaped [1,2]. It is constricted in the middle and expanded above and below. The adult innominate bone is composed of three fused elements: the ilium, ischium and pubis. All three elements contribute to the formation of the acetabulum, but not in equal proportions. The ossification of the acetabulum is discussed in Chapter 5.

The ilium forms the largest part of the innominate bone and acetabulum. It has a widely expanded thin wing or ala, which ends cranially in the iliac crest and expands between the anterior and posterior superior iliac spines. The anterior inferior iliac spine is located on the anterior border of the ilium. At this level, the thin wing of the ilium is broadened to form the body of the ilium, which contributes to the formation of the roof of the acetabulum. On the posterior border of the ilium, the greater sciatic notch extends from the posterior inferior iliac spine to the ischial spine.

The acetabulum is an approximately hemispherical cavity on the lateral aspect of the innominate bone. The bony acetabulum is deepened by the labrum attached to its rim. The caudal margin of this irregularly-shaped rim is deficient: the acetabular notch, which is the site of attachment of the strong transverse ligament. The floor of the acetabular cavity is non-articular and is termed the acetabular fossa. The articular surface of the acetabulum forms an incomplete ring: the lunate surface, which is broadest at its upper, weight-bearing part.

Biomechanically, the pelvis can be considered as a system of arches which support the spine in an upright position. Its most important function is to transmit the weight of the head, trunk and upper limbs to the lower extremities. The pelvis is constructed to withstand compression and other stresses due to the body weight and powerful musculature insertions some distance from the femoral head, thus obtaining greater leverage in stengthening the joint.

The pelvis can be divided into two arches by a frontal plane passing through the acetabular cavities. The posterior of these arches is chiefly concerned with the fuction of transmitting the weight of the trunk. Its essential parts are the upper three sacral vertebrae and two strong pillars of bone running from the sacro-iliac joints to the acetabular fossae. The anterior arch is formed by the pubic bones and their superior rami. The anterior arch acts as a tie-beam or tension band through the ileopectineal line and symphysis pubis to prevent separation of the posterior arch. The anterior arch also functions as a compression strut to resist the medial thrust of the femoral heads. In the sitting position, forces are transmitted from the ischial tuberosities through the ischium to the sacrum and spine. The stability of the pelvic ring depends on the integrity of the posterior weight-bearing sacro-iliac complex. The major forces acting on the pelvis are external rotation (by forced external rotation of the legs), vertical shear and internal rotation (compression from the lateral side or an indirect force through the femoral head). Acetabular fractures occur mainly through the latter type of force [3,4].

The internal structure of the acetabulum reflects its biomechanical function. The acetabulum (with the exception of the acetabular fossa) consists of two thick cortical layers of compact bone, with intermediate layers of cancellous bone. Three major trabecular systems can be identified in the innominate bone: sacro-acetabular; sacro-pubic and sacro-ischial. This trabecular system correlates well with the anterior and posterior column of the acetabulum [5,6]. At the acetabular roof, the compact bone shows increased density, forming a thick massive trabecular structure. This region is very strong and is often referred to as the sciatic buttress [5]. It is only exceptionally involved in fractures.

RADIOGRAPHIC ASSESSMENT

An accurate radiographic examination of the injured acetabulum forms an essential part of the evaluation. A patient with multiple-system injuries is often transported rapidly to the intensive care department or operating theatre, where high-quality radiographic images are difficult to obtain. Therefore, at least a preliminary diagnosis must be established directly on admission of the patient, preferably in a well-equiped casualty department, before the patient is moved. This initial radiographic examination must be tailored to the condition of the patient. A single anteroposterior view of the pelvis is frequently sufficient to establish a preliminary diagnosis in severely traumatized patients. When the condition of the patient is stabilized, additional views may be requested, which should at least include oblique views. It is generally accepted that two projections at right angles to each other are necessary for the evaluation of skeletal injuries. Due to the superimposition of both hips as visualized in the lateral projection, a true lateral view is of no value. Therefore it is essential to obtain oblique views to visualize the whole acetabulum. The anteroposterior (AP) and oblique radiographs must be considered as a basic set of three radiographs which should be obtained in every patient with a (suspected) acetabular fracture. The analysis of these radiographs is often intricate as numerous radiographic lines are superimposed. To enable better and easier radiographic orientation, Weigand and Schweikert [7] introduced five radiographic "guiding" lines, which should be studied carefully on each radiograph, starting from the medial side (near the symphysis) and continuing laterally (Figs 1-3).

These lines are:

L1: The innominate/ileopectineal line or pelvic brim. Extending from the superior margin of the pubic tubercle to the sacro-iliac joint.

L2: Anterior border of the acetabulum. Extending from the inferior margin of the superior pubic ramus to the superior margin of the acetabulum.

L3: Ilioischial line. Extending from the superior margin of the inferior ischio-pubic ramus to the sacro-iliac joint. In an exact AP radiograph, it intersects with Köhler's teardrop (L5) and unites with L1.

L4: Posterior wall of the acetabulum. Extending from the inferior margin of the inferior ischio- pubic ramus to the superior margin of the acetabulum.

L5: Köhler's teardrop and medial acetabular wall.
L5 is the radiographic condensation of both Köhler's teardrop and the medial acetabular wall. At the superior margin of the acetabulum it unites with L2 and L4.

Thus, the anterior column is outlined by L1 and L2; the posterior column by L3 and L4 and the acetabular fossa by L5. With the aid of these lines, fracture classification (Chapter 3) is simplified. Although CT scans or other radiographic imaging techniques may provide additional important information, the careful analysis of these basic radiographs remains of paramount importance.

A radiographic examination of the fractured acetabulum may consist of:

- Anteroposterior radiograph.
- Iliac and obturator oblique radiographs.
- Inlet and outlet radiographs.
- Tomography.
- Computed Tomography.
- Three-dimensional computed tomography.

Each of these techniques will be discussed briefly. Isotope bone scans can be very helpful to disclose subtle stress fractures of the pelvic ring, but are not

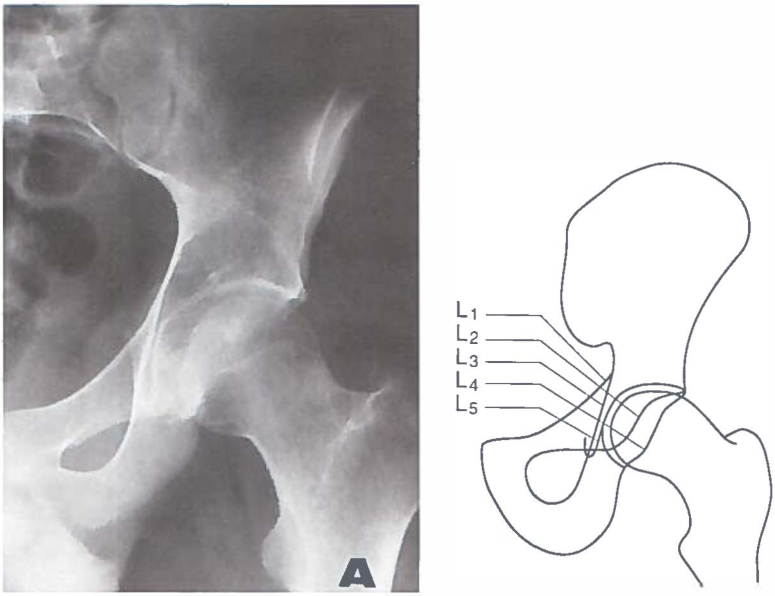

Fig. 1A,B. Anteroposterior projection of the left hip. All five guiding lines are well recognized.

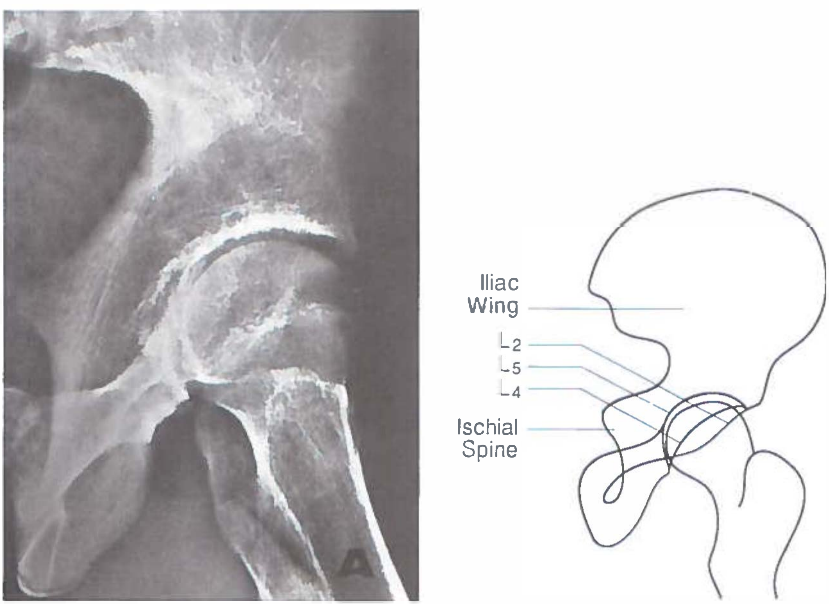

Fig. 2A,B. Iliac oblique (or Ala) projection. The wing of the ilium, the anterior acetabular border (L2) and the posterior margin of the acetabulum with the ischial spine are well outlined.

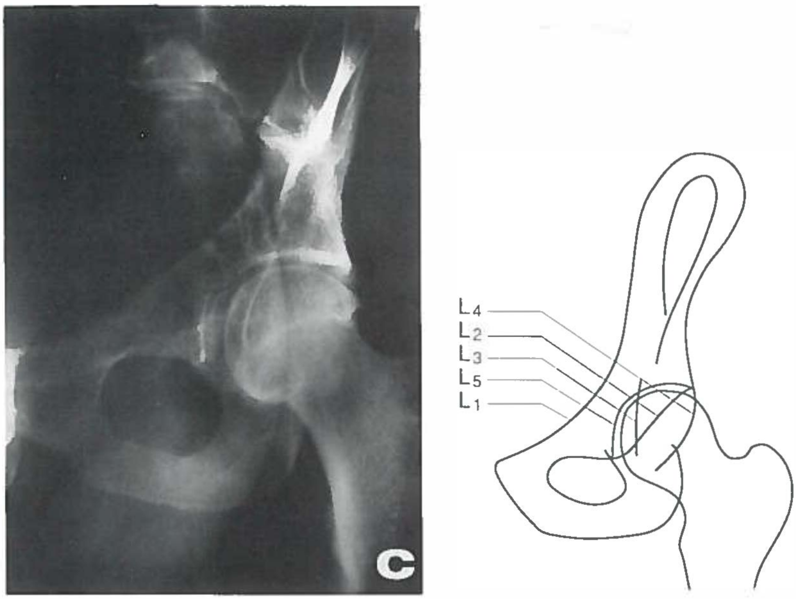

Fig. 3A,B. Obturator oblique projection. The anterior column (L1 and L2) as well as the posterior wall are well displayed.

required for the early diagnosis of acetabular fractures. A systematic imaging approach is required to evaluate the soft-tissue and visceral contents of the pelvis. Numerous techniques are available, but these are not discussed here.

ANTEROPOSTERIOR RADIOGRAPH

Usually, the radiographic beam is directed perpendicular to the midpelvis. This enables an accurate comparison of both hips. With the patient supine, the pelvis is tilted slightly posteriorly [1]. Thus, an AP view gives, in reality, an oblique projection. Generally it is not difficult to recognize an acetabular fracture on a plain AP view, but some acetabular fractures are overlooked if the radiographic examination is confined solely to this view [6,8-11]. In addition, the AP view does not provide sufficient information regarding the amount and direction of fracture displacement and the location of the femoral head. The AP view demonstrates all five guiding lines adequately (Fig. 1). Both hips must be inspected closely for congruity of the joint surface. This is best accomplished superiorly, where the roof of the acetabulum is visualized as a sharply defined cortical line, parallel to the superior aspect of the femoral head. The joint surfaces should be parallel, irrespective of the position in which the radiographs are made. Lack of congruity is an important finding, suggesting entrapment.

The width of the hip joint can be measured in two positions and compared to the opposite hip. Usually these measurements are made at the most superior margin of the femoral head and inferomedially at the level of the teardrop: the teardrop distance. Normally, there should be no more than 1 or 2 mm difference between the two hips, at either point of measurement [12]. Whenever the hip joint space is widened following trauma, it is best to assume the presence of intra-articular fragments untill proven otherwise. The hip joint space is rarely widened by haemarthrosis alone [12], which is well visualized with ultrasound.

An important soft-tissue clue to demonstrate an otherwise occult fracture of the acetabulum, is the unilateral prominence of the fascial plane of the obturator internus muscle (Fig. 4) [13-15]. This fascial plane projects within

Fig. 4. Bulging of the fascial plane of the obturator internus muscle in a patient with a rim fracture of the acetabulum (not visible on this radiograph).

the pelvis on the medial surface of the muscle. Although its degree of visibility is quite variable and it may even be present without any underlying pathology, if it is present unilaterally and is prominent, damage to the acetabulum with haemarthrosis must be suspected [16].

The most common and confusing normal variant which might be mistaken for a fracture, is the roentgenologic os acetabuli. This secondary centre of ossification at the superior lateral margin of the acetabulum usually appears between the age of 14 and 18 years (Fig. 5). It may persist unfused, uni or bilaterally [17-19].

Fig. 5. The roentgenologic os acetabuli is a secondary centre of ossification, which is easily mistaken for a fracture of the posterior wall.

ILIAC AND OBTURATOR OBLIQUE RADIOGRAPHS

These views are mandatory for a complete examination of the acetabulum. Without these views, the full extent of the injury and the degree of fracture displacement will definitely be missed. Both oblique views are obtained in the supine position. The best views are obtained with a stationary radiographic tube, while the patient's hip is tilted. If this position is too uncomfortable for the patient, the tube can be angled also, but the quality of these radiographs is usually inferior [12-20].

On the ILIAC OBLIQUE radiograph (Fig. 2), the uninjured hip is tilted 45 degrees towards the radiographic beam. The affected hip is thus visualized in external rotation, with a clear view of the ilium. Therefore this view is also referred to as external oblique or ala view [6].

The iliac oblique view demonstrates [21-23]:

- the wing of the ilium,
- the anterior border of the acetabulum (L2),
- the posterior margin of the innominate bone, with the ischial spine.

On the OBTURATOR OBLIQUE radiograph (Fig. 3), the affected hip is tilted 45 degrees towards the radiographic beam. As the affected hip is thus visualized in internal rotation, it is also referred to as internal oblique view. This view demonstrates [21- 23]:

- the whole anterior column (L1 and L2),
- the posterior wall (L4) and
- the obturator foramen.

INLET AND OUTLET RADIOGRAPHS

These radiographs are not performed routinely at our hospital, but they may provide important information [8,22]. To obtain these views, the radiographic beam is tilted in a sagittal plane, while the patient remains supine.

In the INLET VIEW (Fig. 6A), the beam is directed caudad at an angle of 25-40 degrees in the sagittal plane i.e. perpendicular to the plane of inlet of the pelvis. This view makes the pelvis appear as a ring. It defines the rotational deformity as well as the amount of medial fracture displacement. This projection also shows sacro-iliac dislocation and the degree of displacement of sacral fractures.

On the OUTLET VIEW (Fig. 6B), the radiographic beam is tilted 35 degrees cephalad to the symphysis. The amount of superior or inferior displacement of segments of the pelvis can be determined.

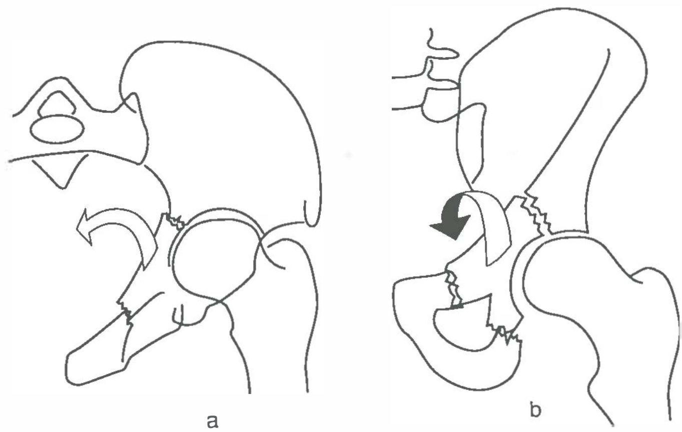

Fig. 6A,B. Inlet and outlet views of the pelvis.
Fig. 6A: Inlet view; the radiograhic beam is tilted 25 degrees caudad in the sagittal plane. Fig. 6B: Outlet view; the radiographic beam is tilted 35 degrees cephalad.

TOMOGRAPHY

Linear and especially multiplanar tomography can be useful in the evaluation of acetabular fractures, but its role is limited now that CT scanning has become widely available. Nevertheless, tomography may be helpful in evaluating the position of intra-articular fragments, the amount of comminution, the damage to the femoral head, the congruity of the acetabular dome and fracture union. If the level of thin-sectioned multiplanar tomography is not chosen carefully, false negative information can easily be obtained [24-26].

COMPUTED TOMOGRAPHY

Since its introduction, computed tomography has become increasingly popular in facilitating the traditional classification and diagnosis of acetabular fractures. Especially the junction of both columns, the acetabular roof and the medial acetabular wall are poorly visualized by conventional radiography. This area is well visualized by CT. Although CT has many advantages compared to conventional radiography, it must be remembered that even with CT, pure cartilaginous damage is not visualized [27]. Using CT, the patient does not have to be moved as is the case when obtaining oblique radiographs. However, the patient must be well enough to maintain a stationary position during the procedure.

Apart from the standard technique of CT, in which transverse views of the pelvis are obtained, a special angled technique has been described [28]. This technique allows the visualization of the pelvis as a complete ring on a single image. The patient is placed in Trendelenburg position on a trauma board. The gantry is angulated 20 degrees from the transverse plane towards the feet. This technique provides an improved view of the pelvis as a continuous ring. The posterior/superior wall of the acetabulum is particularly well-outlined.

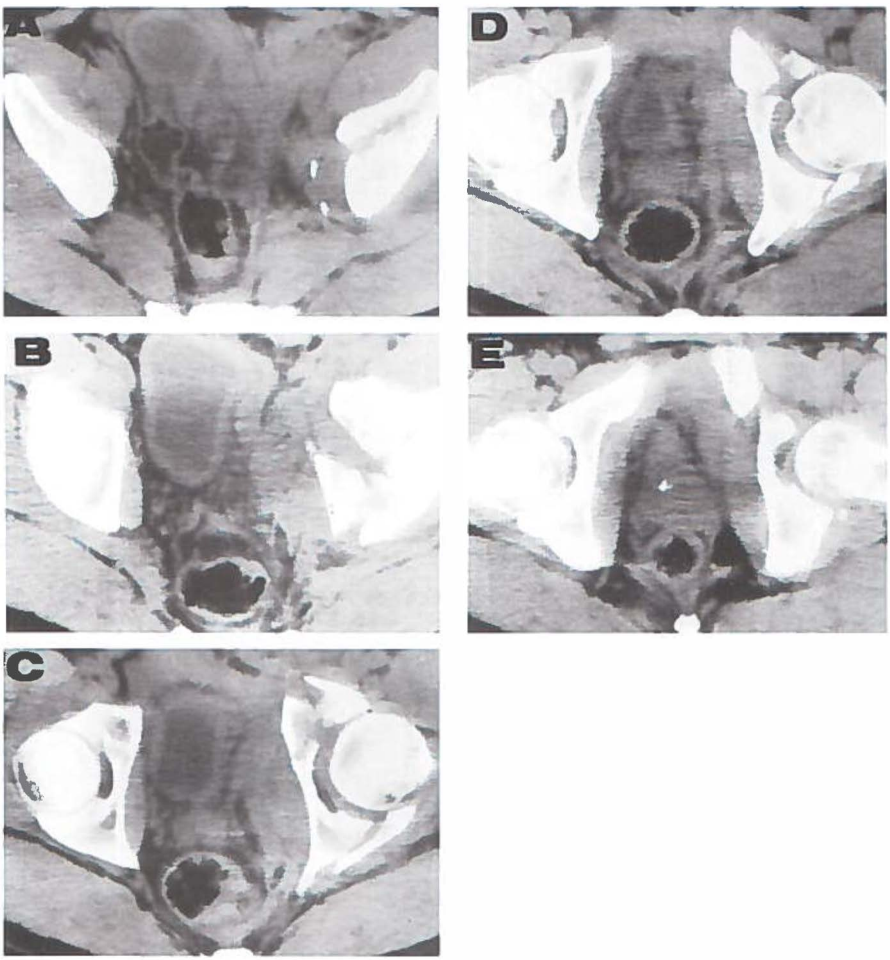

Fig. 7A-E. CTscan of a both colums fracture. A: Extension of the fracture in the iliac wing. B: Acetabular roof level. C: Acetabular fossa level. Extension of the fracture through anterior and posterior column is seen. D: Greater trochanter level. E: Dislocation of anterior column, slightly above symphysis pubis level.

The advantages of CT are:

- CT may disclose unsuspected acetabular or pelvic ring fractures [29-32]. CT has been reported to be more sensitive than plain radiography in detecting fractures involving the acetabular roof and posterior wall [33]. A higher sensitivity in the detection of anterior wall fractures has been reported [34] but this has been disputed by others [33].
- CT improves the spatial resolution in fracture patterns and therefore facilitates classification. Especially the complex three-dimensional configuration of a both columns fracture is better outlined (Fig. 7) [35-37].
- CT facilitates the detection of intra-articular and femoral head fragments (Fig. 8) [38-39].
- The size and stability of a posterior wall fragment can be determined. If 40 per cent of the posterior wall is fractured (measured in the transverse plane), the hip is always unstable. This investigation may be of importance when the stability of the hip cannot be tested, as in ipsilateral femoral neck or shaft fractures [40].
- The associated soft-tissue injuries and haematomas of the pelvis are better identified [41-42].
- CT may be useful in the immediate postoperative period for detecting residual intra-articular fragments, assessing the adequacy of reduction and ascertaining that the fixation material is not positioned intra-articularly [43].

Fig. 8. Intra-articular posterior wall fragment.

THREE-DIMENSIONAL COMPUTED TOMOGRAPHY

Recently available computer programmes produce three-dimensional surface reformations of complex anatomical structures from sets of axial CT scans [44-48]. This technique provides a unique perspective of acetabular fractures, not obtainable by other means (Fig. 9). Projections in virtually any

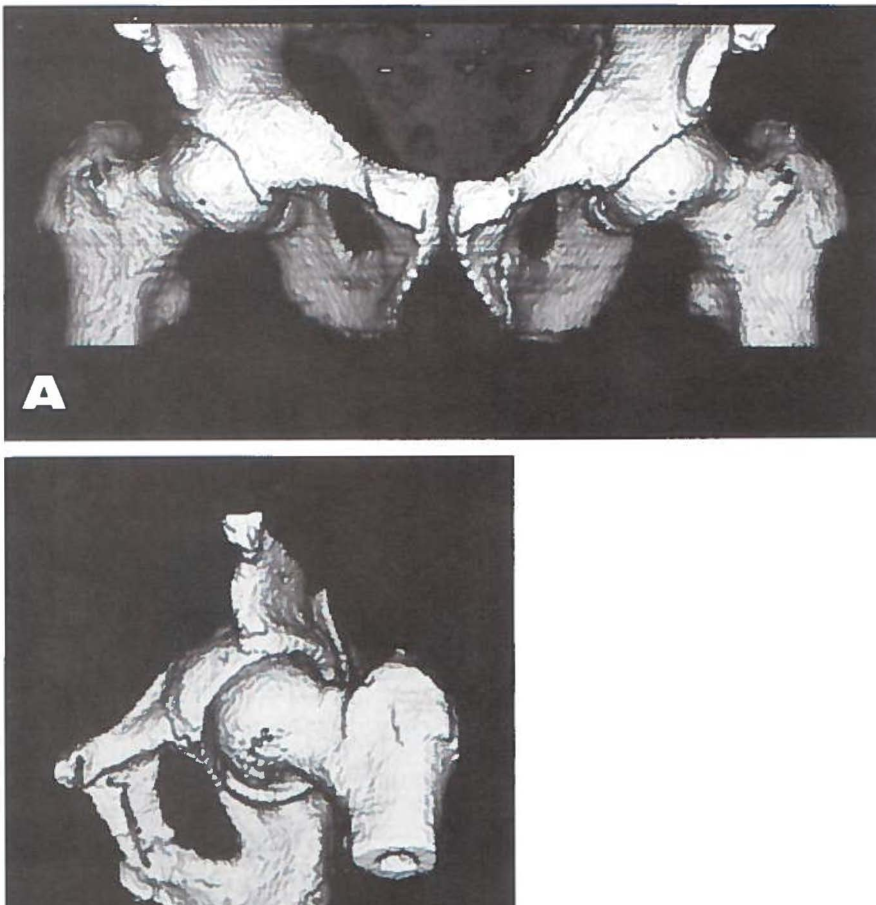

Fig. 9A,B. Three-dimensional reconstruction of a minimally displaced posterior column fracture. Fig. 9-A: frontal view of the pelvis, to demonstrate the details of both hip joints. Fig. 9-B: detail of the left hip, in the obturator projection. The fracture is now visualized. For a complete three-dimensional reconstruction of the pelvis, 45 slices are required, with a slice increment of 2mm. (Courtesy of Philips Medical Systems, The Netherlands).

orientation can be obtained. The femoral head can be substracted to inspect the articular surface of the acetabulum. The value of three-dimensional computed tomography in the analysis of acetabular fractures has not yet been determined but seems promising.

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Chapter 3

Fracture classification

INTRODUCTION

The ideal classification of acetabular fractures is clear, reproducible, based on anatomical characteristics and bear implications on treatment and prognosis. Since the first reports of acetabular fractures, numerous classifications have been introduced. Basically these classifications made only a crude distinction between three fracture types:

- linear fractures with no or little displacement,
- fractures with posterior dislocation of the femoral head and
- fractures with central dislocation.

As surgical treatment gained popularity, the need for a more refined classification became evident. French surgeons have contributed significantly to these developments, as has been described in Chapter 1. In 1951, Cauchoix and Truchet described intermediary fracture types, such as a combined posterior wall fracture associated with central dislocation of the femoral head and trans-acetabular factures with posterior dislocation of the femoral head [1]. Creyssel and Schnepp (1961) proposed a new classification based on 'principal' and 'accessory' fracture lines [2]. As a whole, their classification was rather complicated and not reproducible.

Unsatisfactory with the existing classifications, Letournel and Judet performed an extensive clinical-radiographical study of 632 acetabular fractures [3]. As 90 per cent of these fractures were treated surgically, the radiographical and surgical findings could be correlated. In 1959, they identified the posterior column fracture, which could be separated from the large, unspecific group of 'central fracture-dislocations'. Later, fractures of the anterior column (1960); both columns (1961) and anterior wall (1968) were distinguished. Letournel and Judet stated that the acetabulum can be regarded as being contained within the arms of an inverted Y, formed by two columns of bone, one anterior and one posterior (Chapter 1: Fig. 7). The posterior or ilio-ischial column is a thick, short, solid bone plate which extends from the region of the inferior sacro-iliac joint to the ischial tuberosity. The anterior or ilio-pubic column is much longer and extends from the anterior end of the iliac crest to the symphysis. Both columns converge above the acetabulum in a thick compact zone of bone, which supports the roof of the acetabulum. The concept of the both columns classification is supported by studies on bony trabecular architecture of the innominate bone (Chapter 2).

Letournel and Judet made a division between five elementary or simple fractures (which encompass single, clearly recognisable lesions of the respective walls and columns, and an additional solitary fracture type: the transverse fracture) and five associated or complex fractures, which are combinations of the elementary types (Table I; Fig. 1).

Table I. Fracture classification.

ELEMENTARY:	1. Posterior wall	
	2. Posterior column	
	3. Anterior wall	
	4. Anterior column	
	5. Transverse	
ASSOCIATED:	6. T-shaped	
	7. Posterior column and posterior wall	
	8. Transverse and posterior wall	
	9. Anterior wall/column, posterior hemitransverse	
	10. Both columns	
OTHER:	11. Triradiate cartilage:	type 1
		type 2
		type 5

Since the introduction of this classification in 1964 [4] it became increasingly popular. The classification has two distinct disadvantages however:

- Letournel and Judet described numerous atypical and transitional fracture types, which makes their classification complex. In this thesis, fractures are only classified as pure elementary or associated fractures.

- Fractures through the acetabular triradiate cartilage in children are not identified as a specific category of fractures, which need further specification. To overcome this inconsistency, Bucholz et al (1982) [5] introduced an adapted Salter-Harris classification [6], which is now generally accepted [7] (Table I.).

Despite these disadvantages, the Letournel-Judet classification has been of paramount importance in the development of treatment of acetabular fractures. As most of the criteria for an ideal classification are met, comparison between different series of acetabular fractures is now possible and useful.

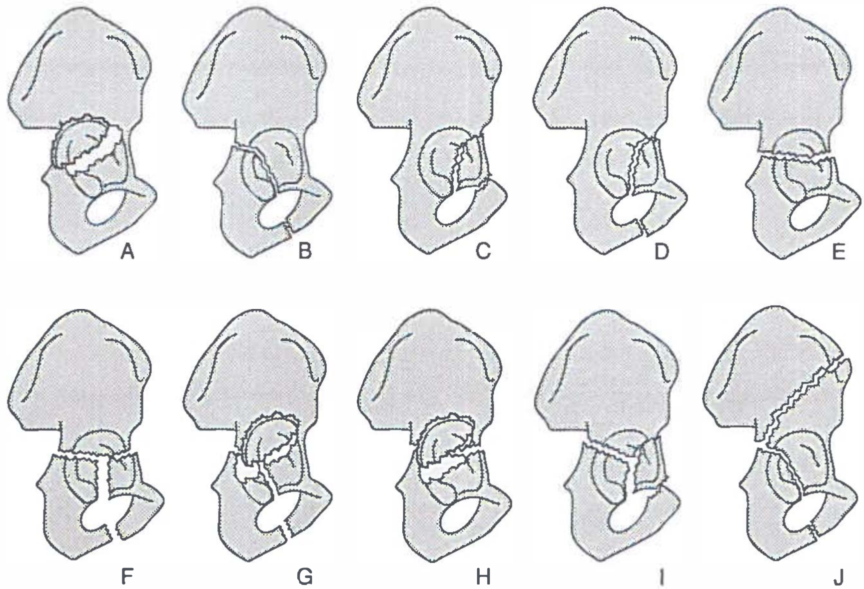


Fig. 1. Fracture classification according to Letournel and Judet. A: posterior wall; B: posterior column; C: anterior wall; D: anterior column; E: transverse; F: T-shaped; G: posterior column and posterior wall; H: transverse and posterior wall; I: anterior wall or column and posterior hemitransverse; J: both columns.

In the next sections of this chapter, the radiographical details of the Letournel-Judet and triradiate cartilage classifications will be described and illustrated per fracture type.

To facilitate fracture analysis, the radiographical guiding lines as described in Chapter 2 should be studied in all projections. The following aspects should be considered:

- L1, the ileopectineal line and L2, the anterior border of the acetabulum are interrupted in all fracture types, except the posterior wall and posterior column fractures.

- L3, the ilioischial line is interrupted in posterior column and transverse fractures, as well as all associated fracture types.

- L4, the posterior border of the acetabulum is interrupted in all fracure types, except anterior wall and anterior column fractures.

- The roof of the acetabulum is usually spared in anterior wall, transverse and T-shaped fracures. In both columns fractures, the roof is always completely separated from the iliac wing. In the remaining fracture types, the roof is separated in a variable degree.

- The iliac wing is always fractured in a both columns fracture. In the anterior column fracture and associated anterior plus posterior hemitransverse fracture, the iliac wing is frequently fractured.

- The obturator ring is not interrupted in posterior wall and transverse fractures; in T-shaped fractures it is always interrupted. In other fracture types it may be interrupted, depending on the plane of the fracture.

Although only classification criteria are discussed extensively in this chapter, other radiographic characteristics should also be studied in each fracture. These include:

- degree of comminution,
- direction of displacement and possible fracture or impaction of the femoral head.
- degree of osteoarthritis and osteoporosis at the time of injury.

POSTERIOR WALL FRACTURE

This is the most common type of acetabular fracture. Strictly speaking, it is a partial fracture of the posterior column and could be classified as such. However these fractures are radiographically clearly recognizable as a specific entity and classified as such.

Depending on the plane of the fracture, a variable segment of the acetabular roof is detached, leaving the major portion of the posterior column undisturbed (Fig. 2). Although the posterior wall fragment is usually disrupted from the postero-superior acetabular rim, it may be very large and detach the whole posterior wall extending inferiorly as far as the midlevel of the obturator foramen (see Fig. 19).

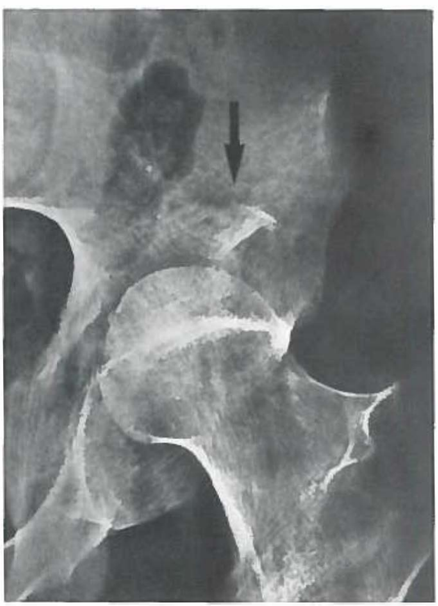
Small osteochondral fragments are often impacted into the margin of the fracture, a phenomenom which has been called marginal impaction by Letournel and Judet.

Similarly, the subchondral bone of the fractured acetabular rim may be compressed. If the posterior wall fragment is reattached surgically, the two fracture surfaces may not fit exactly. This phenomenom is not seen on routine radiographs, but can be visualized with computed tomography.

RADIOGRAPHY: (Figs 3-5)

AP:	*L4 is interrupted. *The anterior border of the acetabulum and teardrop are intact.
Obt Obl:	*The size of the detached fragment is revealed. *The posterior (sub)luxation of the femoral head, if present, is demonstrated. *The obturator ring, anterior wall and anterior column are intact.
Iliac Obl:	*The disruption of L4 and the position of the posterior wall fragment are often hardly seen (arrow). *The anterior wall is intact.

Fig.2



Posterior wall fracture.

Fig.3 (top left):	AP view,
Fig.4 (top right):	Obt. obl. view,
Fig.5 (bottom):	Iliac obl. view.

POSTERIOR COLUMN FRACTURE

The fracture line extends from the greater sciatic notch through the acetabulum to the obturator foramen, splitting the ischio-pubic ramus, usually in its midportion (Fig. 6). The pelvic teardrop is not disrupted. In the typical case, the whole posterior column is detached in one fragment and driven medially and posteriorly. The femoral head follows this direction of displacement and remains more or less congruent with the articular surface of the posterior wall. The thick part of the acetabular roof is often intact.

RADIOGRAPHY: (Figs 7-9)

AP:

*L3, L4 and L5 are interrupted.
*L1 and L2 (the anterior column) are intact and its contours are very clear due to the inward displacement of the posterior column, which is normally superimposed.

Obt Obl:

*L1 and L2 are intact.
*A large part of the roof is intact.
*The superior limit of the fracture through the posterior column is difficult to see, due to superimposition of the femoral head.

Ilac Obl:

*L2 and the roof are intact.
*The superior limit of the fracture is clearly outlined.
*(In the presented example an indentation of the femoral head is seen, marked with an arrow, which is not visible on other radiographs).

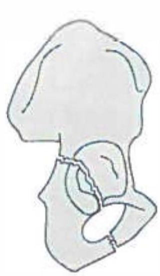


Fig.6

Posterior column fracture.

Fig. 7 (top left):	AP view,
Fig. 8 (top right):	Obt. obl. view,
Fig. 9 (bottom):	Iliac obl. view.

ANTERIOR WALL FRACTURE

The fracture line extends from or below the anterior inferior iliac spine, through the acetabulum to the obturator foramen. The superior ramus of the pubic bone is fractured (Fig. 10). Anterior wall fractures are partial fractures of the anterior column, but radiographically, they form a specific group. The fracture results in the separation of a large part of the middle third of the anterior column, including the anterior part of the articular surface and the upper part of the superior pubic ramus. The femoral head may be (sub)luxated anteriorly. The diagnosis is often clear on a single AP view.

RADIOGRAPHY: (Fig. 11)

AP:	*L1 and L2 are interrupted; the pelvic teardrop may be interrupted. *L3 and L4 (the posterior column) are intact.
Obt Obl:	*The extent of the fracture through L1 and L2 is demonstrated.
Iliac Obl:	*The outline of the fracture is hardly or never seen. *The integrity of the posterior column is confirmed.

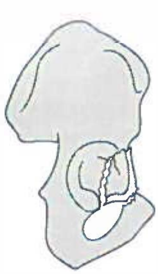


Fig. 10

Anterior wall fracture.

Fig. 11: AP view.

ANTERIOR COLUMN FRACTURE

The superior limit of the fracture may extend proximally to the anterosuperior edge of the iliac wing. The fracture passes through the acetabulum and obturator ring to the ischio-pubic ramus (Fig. 12). Depending on the cranial boundaries of the fracture, very low as well as very high fractures exist. The very low fractures leave a large part of the articular surface intact. Differentiation between very low anterior column fractures (in which at least part of the articular surface is involved) and fractures of the pubic bone (in which the articular surface is intact) is sometimes difficult. With computed tomography, information can be obtained about the localization of the fracture in this region. At the other side of the spectrum is the high anterior column fracture, which results in separation of nearly the whole articular surface as well as the roof and part of the iliac wing.

Usually the femoral head follows the displaced anterior column and remains (sub)luxated anteriorly or centrally.

RADIOGRAPHY: (Figs 13-14)

AP:	*L1 and L2 are interrupted; L5 may be interrupted. *L3 and L4 are intact.
Obt Obl:	*Demonstrates the upper limit of the fracture through L1 and L2 and the site of fracture through the ischio-pubic ramus.
Iliac Obl:	*L4 is intact.

Fig. 12

Anterior column fracture.

Fig. 13 (left): AP view.
Fig. 14 (right): Obt. obl. view.

TRANSVERSE FRACTURE

The fracture line transects the innominate bone into an upper and a lower segment: essentially the ilium and the ischio-pubic fragment (Fig. 15). It is very important to understand the difference between the transverse fracture and the both columns fracture, although both columns have been fractured in each fracture type. In contrast to the both columns fracture, the transverse fracture is a one plane fracture, in which the obturator ring is always intact. A variable part of the acetabular roof is separated, depending on the plane of the fracture. In all transverse fractures, however, an unfractured segment of the roof remains in contact with the iliac wing. The femoral head is dislocated centrally.

RADIOGRAPHY: (Chapter 6, Figs 1A-C)

AP:	*L1-L5 are all interrupted. *The roof is involved in a variable way. *The obturator ring is always intact.
Obt Obl:	*The degree of central dislocation of the femoral head and the integrity of the obturator ring are demonstrated.
Iliac Obl:	*The superior fracture limit through the greater sciatic notch is outlined.

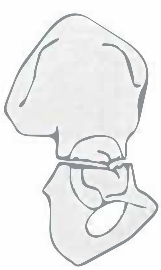


Fig.15

POSTERIOR COLUMN AND POSTERIOR WALL FRACTURE

Both components of this associated fracture-type are identical to the elementary fracture types. We have not encountered this type of fracture and cannot demonstrate its radiographical characteristics.

According to Letournel and Judet, the fracture of the posterior column is often incomplete or minimally displaced. Depending on the fracture-plane, the acetabular roof is detached in a variable way (Fig. 16). Usually a posterior dislocation is present.

RADIOGRAPHY:

AP:	*L3 and L4 are interrupted. *L1 and L2 are intact.
Obt Obl:	*The integrity of L1 and L2 is confirmed. *The size of the posterior wall fragment is revealed.
Iliac Obl:	*The superior fracture limit and amount of displacement of the posterior column fracture is demonstrated.

Fig. 16

T-SHAPED FRACTURE

A transverse fracture is combined with an oblique or vertical splitting fracture of the obturator ring (Fig. 17). The transverse element of this fracture type is identical to the pure transverse fracture. The vertical component of the fracture is directed either:

- anteriorly (in the direction of the pubic tubercle),
- vertically (splitting the obturator ring in the middle) or
- posteriorly (separating a portion of the body of the ischium).

The vertical type of fracture is illustrated in fig. 18; the posterior type in Fig. 19. The posterior type of T-shaped fracture is in fact indistinguishable from the associated Transverse-Posterior wall fracture. In both types, the pelvic roof remains attached to the iliac wing. The femoral head is usually dislocated centrally. The diagnosis of this fracture type can usually be made from a single AP view.

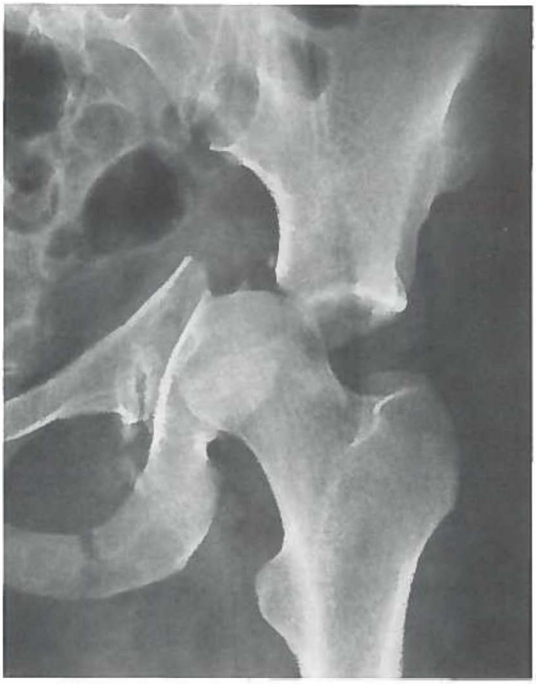
RADIOGRAPHY: (Figs 18,19)

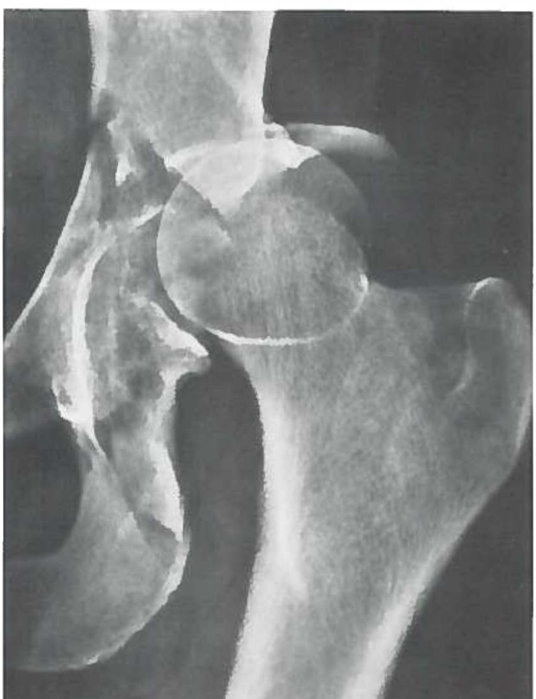
AP:
*L1-L5 are all interrupted.
*Displacement at the transverse component is usually significant (Fig. 18).
*The pelvic teardrop is frequently interrupted.

Obt Obl:
*The vertical component of the fracture through the obturator ring or body of ischium is demonstrated.

Iliac Obl:
*The configuration of the fracture through the posterior column is demonstrated.

Fig.17





T-shaped fracture.

Fig. 18 (top); Fig. 19 (bottom): two examples.

TRANSVERSE AND POSTERIOR WALL FRACTURE

This is one of the most common forms of acetabular fractures. Depending on the plane of the transverse component, the roof is involved in a variable way. Usually the transverse component is situated just below the acetabular roof, leaving its major portion intact (Fig. 20). The pelvic teardrop is not interrupted in these cases.

The femoral head is usually dislocated posteriorly and less frequently centrally. The obturator ring is intact.

The differentiation between the T-shaped fractures with a huge posterior-vertical component (Fig. 19) and the associated transverse-posterior wall fracture may be difficult.

RADIOGRAPHY: (Figs 21-23)

AP:	*L1-L5 are all interrupted. *The plane of the transverse component can be determined. *A variable part of the roof is intact. *The size and degree of comminution is outlined.
Obt Obl	*The obturator ring is intact. *The extension of the posterior wall fracture is demonstrated. *The teardrop is intact.
Iliac Obl	*The integrity of the iliac wing is confirmed. *The outline of the fracture through the posterior acetabular border is demonstrated.

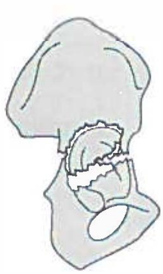


Fig.20

Transverse and posterior wall fracture.

Fig.21 (top left):	AP view,
Fig.22 (top right):	Obt. obl. view,
Fig.23 (bottom):	Iliac obl. view.

ANTERIOR WALL/COLUMN AND POSTERIOR HEMI-TRANSVERSE FRACTURE

We have encountered only one patient with this type of fracture. The description of this fracture is therefore based on the work of Letournel and Judet [3]. The radiographical analysis of this fracture type is rather complicated. It is the association of a fracture of the anterior column or wall, with a fracture of the posterior column (Fig. 24). As the posterior column fracture is identical to the posterior half of a pure transverse fracture, this fracture type was designated "hemitransverse posterior fracture" by Letournel. Both anterior and posterior lesions are identical to the elementary lesions.

The anterior lesion leads to an anterior or, less frequent central displacement of the femoral head. The displacement of the anterior wall or column is usually significant.

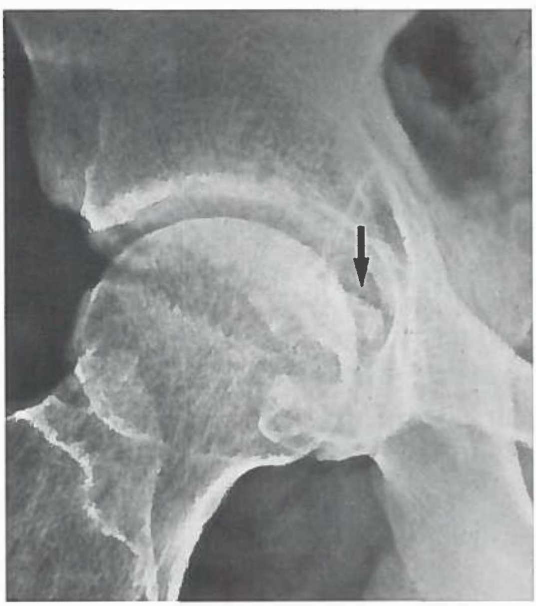
The main difficulty lies in the recognition of the posterior column fracture. Displacement of this component is often insignificant, complicating the radiographical detection.

An important differentiation with the both columns type of fracture is the fact that in the anterior column/posterior hemitransverse fracture, a segment of the acetabular roof remains always intact to the wing of the ilium, in contrast to the both columns fracture.

RADIOGRAPHY: (Figs 25,26)

AP:	*L1-L5 are all interrupted. *The femoral head is dislocated anteriorly. *The anterior column fracture is clearly outlined. *A segment of the ischial spine is fractured, indicating a fracture of the posterior column!
Obt Obl	*The fracture through the posterior column, if significantly displaced (not visible in this patient) is outlined.
Iliac Obl	*The posterior column element of the fracture is outlined, but may be very difficult to visualize. In this case, the fractured fragment of the posterior column gives the impression of being incarcerated intra-articularly (arrow). This is not the case however. *The anterior column is clearly fractured.

Fig.24



Anterior column and posterior hemitransverse fracture.

Fig.25 (top): AP view.
Fig.26 (bottom): Iliac obl. view.

BOTH COLUMNS FRACTURE

A high, more or less transverse fracture separates the comlete distal pelvis, including the acetabulum, from the iliac wing. A second vertical fracture line, usually in the form of a T or Y, extends from the fracture downwards, through the acetabulum to the obturator foramen. This second fracture line separates the anterior and posterior columns from each other (Fig. 27).

In its most simple form, both the anterior as well as the posterior column separate as a whole from the iliac wing. The acetabular roof is completely detached from the iliac wing, and remains either attached to the anterior column or is seen as a separate fracture.

Frequently, however, the configuration of the fracture is far more complicated, as the major components are crossed by other, supplementary fracture lines. This complicates fracture classification. The diagnosis is not as complicated as it may seem at first glance, due to a rather constant radiographic finding in both column fractures: the so-called spur sign (Letournel [3]). The spur sign is demonstrated on the obturator oblique view and is the radiographic demarcation of the transverse element of the both columns fracture at the supra-acetabular region, through the wing of the ilium. As the lower pelvic segment, including the acetabulum, is displaced medially, the interruption of the outer iliac border is visualized as a spur.

RADIOGRAPHY: (Figs 28-30)

AP:	*L1-L5 are all interrupted. *The femoral head is dislocated centrally. *Displacement of the posterior column is signifcant. *A huge segment of the roof is separated, remaining in contact with the femoral head. *The extension of the anterior column fracture in the iliac wing may be seen as a reduplication.
Obt Obl	*The roof is separated from the iliac wing. *The spur sign is clearly outlined (arrow).
Iliac Obl	*The iliac wing fracture configuration and displacement of the posterior column is outlined.

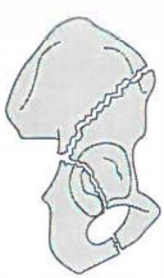


Fig.27

Both columns fracture

Fig.28 (top left): AP view,
Fig.29 (top right): Obt. obl view,
Fig.30 (bottom): Iliac obl. view.

TRIRADIATE CARTILAGE FRACTURE

The complicated three-dimensional configuration of the triradiate cartilage is discussed and illustrated in Chapter 5.

Triradiate cartilage fractures constitute a specific category of fractures, with specific radiographic characteristics. As these fractures are physeal injuries, they can be classified as such. The classification which has been generally accepted was proposed by Bucholz in 1982 [5], based on the Salter-Harris classification (1963 [6]) of physeal plate injuries in general. As only type 1, 2 and 5 physeal plate injuries of the triradiate cartilage have been reported, (Fig. 31) other fracture types are not discussed here.

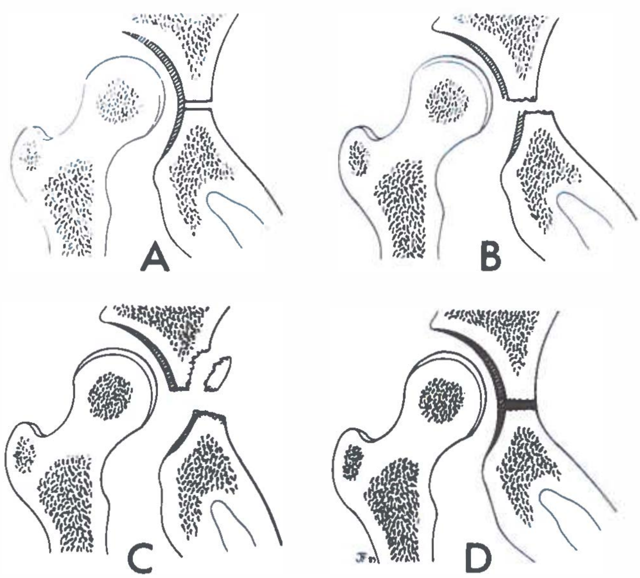


Fig. 31. Fractures of the triradiate cartilage. A: normal hip; B: Type 1 injury; C: Type 2 injury with Thurston-Holland sign (see text); D: Type 5 injury, with compression of the growth plate. (Reproduced with permission after: Scuderi G, Bronson MJ. Triradiate cartilage injury. Report of two cases and review of the literature. Clin Orthop 1987;217:179-189).

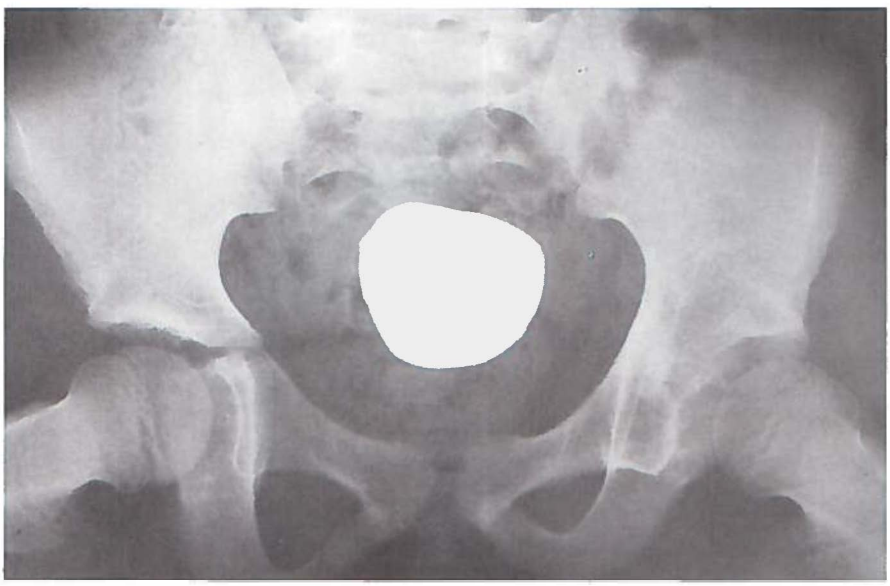
Both type 1 and 2 injuries result from a shearing force, which causes a separation of the physis at the interface of the upper limbs of the triradiate cartilage and the metaphyseal spongiosa of the ilium. In type 1 fractures, the acetabulum is split in two parts, which is well visible on a pelvic radiograph (see Chapter 5 for illustration).

Type 2 fractures are easily recognized by the presence of a medial triangular metaphyseal fragment, often referred to as the Thurston-Holland sign (Ogden, 1982 [8]). This is illustrated in Figure 32. In both type 1 and 2 fractures, the acetabulum is divided in a superior (main weight-bearing) one third and an inferior (minimally weight-bearing) two-thirds.

Fig. 32. A type 2 triradiate cartilage injury with the Thurston- Holland sign.

Although a comparable disruption between the vertical limb of the triradiate cartilage and the metaphyses of the pubis or ischium is theoretically possible, this has never been reported.

Type 5 physeal fractures result from a crushing injury at the site of the physis. Therefore, minimal fracture displacement is present. Every narrowing of the triradiate cartilage should be studied suspiciously. These injuries are difficult to recognize on the initial radiographs and the diagnosis is frequently missed, until a characteristic growth disturbance of the physis is demonstrated radiographically (Figs 33,34). This mechanism is discussed in Chapter 5.



Figs 33 and 34. A three-year-old girl with a fracture through the left pubis and ischium (Fig.33, top). A type 5 injury of the triradiate cartilage could not be recognized on the initial radiographs.
Fig. 34 (bottom): a radiograph taken six years later, at the age of nine, demonstrates complete closure of the triradiate cartilage, with progressive subluxation of the femoral head.
(Courtesy of Dr. R.M. Castelein, Department of Orthopaedic Surgery, Ziekenhuis De Weezenlanden, Zwolle).

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Chapter 4

Acetabular fractures in children and adolescents

Minne Heeg (1), Henk J. Klasen (2) Jan D. Visser (1)

(1) Department of Orthopaedic Surgery
(2) Department of Traumatology
University Hospital Groningen, The Netherlands

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SUMMARY

A retrospective study of 23 acetabular fractures in patients up to 17 years of age is presented, with an average follow-up of eight years. Good or excellent functional results were achieved in 21 patients; radiographic results were good or excellent in 16. Conservative treatment gave consistently good results in fractures with minimal initial displacement, stable posterior fracture-dislocations and Salter-Harris type 1 and 2 triradiate cartilage fractures. Less favourable results were seen in type 5 triradiate cartilage fractures and in comminuted fractures, but operation was no better. Unstable posterior fracture-dislocations and irreducible central fracture-dislocations need operative treatment but the results may still be unsatisfactory.

INTRODUCTION

Acetabular fractures in children and adolescents are very rare. Although many reports of such fractures in adults have appeared in the literature, those in children have received little attention.

A child's pelvis differs markedly from an adults: it is more malleable and the increased joint elasticity allows significant displacement, so that single breaks in the pelvic ring can occur (Canale and King 1984). The other important difference between paediatric and adult acetabular fractures is that the triradiate cartilage may be damaged in children, which can lead to subsequent growth disturbance of the acetabulum (Heeg, Visser and Oostvogel 1988). Reports on other long-term sequelae of acetabular fractures in children are scarce. We have therefore performed a retrospective study to analyse the long-term results and we propose a treatment strategy.

PATIENTS AND METHODS

During the period 1972 to 1985, 27 patients up to 17 years old were treated in our hospital for acetabular fractures. Two patients died immediately after the accident and two could not be traced. Therefore, 23 patients were available for follow-up. A report of four of these patients, all with triradiate cartilage injuries, has already been published in this journal (Heeg et al. 1988). Of the 23 patients, 16 were boys and seven girls; the right hip was affected in 16 cases and the left in seven. The average age of the patients at the time of injury was 13.1 years (range two to 17 years). Seventeen injuries were due to high-energy traffic trauma and four were sustained from horse riding. All patients had an Injury Severity Score of 18 or more (Baker et al. 1974) and ten had associated limb fractures. Eight patients sustained primary nerve injuries (four with lumbosacral plexus lesions and four with peroneal nerve palsy). In 12 patients there was also dislocation of the femoral head: nine posterior and three central dislocations. All dislocations except one, were reduced under general anaesthesia within 24 hours of the accident. Eighteen patients were treated conservatively, and five surgically. The indications for conservative treatment were: minimal displacement in six patients; successful, stable, closed reduction of the femoral head in six; triradiate cartilage fractures without interposition in five; and in one patient severe comminution, with posterior dislocation, in which it was assumed that surgery would not improve reduction or stabilisation (Figs 1 and 2).

The indications for operative treatment were: unstable posterior fracture-dislocation in two patients and irreducible central fracture-dislocation in three.

Conservative treatment consisted of supracondylar or tibial traction in 16 patients. Seven patients were treated with simple bedrest as traction could not be applied for various reasons, such as contaminated wounds and concomitant fractures of the affected leg. The average period of skeletal traction was 4.2 weeks (range two to seven weeks). Traction was followed by progressive weight-bearing, either directly or after a period of simple bedrest. The average interval between the accident and full weight-bearing was 10.1 weeks (range four to 24 weeks). Operative treatment consisted of open reduction and internal fixation in four patients. In one patient an arthrotomy was performed to remove loose osteochondral fragments. Postoperative treatment consisted of bedrest in suspended traction for six weeks, followed by progressive weight-bearing for another six weeks. Full weight-bearing was allowed after three

Figs 1 and 2. A 15-year-old boy with a comminuted transverse acetabular fracture with posterior dislocation of the right hip. Figure 1 (top): On admission. The hip was reduced under general anaesthesia; a CT scan showed extensive comminution, so the patient was treated conservatively. Figure 2 (bottom): Six years after injury the functional result was good, the radiographic result fair.

months. The fractures were classified according to Letournel and Judet (1981), with additional classification of triradiate cartilage fractures (Salter and Harris 1963) (Table I). Displacement was measured on all radiographs; a displacement of 2 mm or less was considered to be congruent.

Follow-up was performed an average of eight years after the accident (range three to 17 years) and consisted of clinical examination and radiography (anteroposterior pelvic view, obturator and iliac oblique views). The functional result was evaluated using the Harris hip score in which pain, function, absence of deformity and range of motion are assessed, with a possible maximum score of 100 points (Harris 1969). The result was classified as excellent with a score of 91-100 points; good with 81-90 points; fair with 71-80 points and poor with ≤70 points. The criteria for degenerative radiographic changes are shown in Table II.

Table I. Classification of the 23 fractures

Fracture type:	Number:
Posterior wall	7
Posterior column	2
Anterior wall	1
Anterior column	2
Transverse	4
T-shaped	–
Posterior column and posterior wall	–
Transverse and posterior wall	1
Anterior wall and posterior column	–
Triradiate cartilage:	
type 1	2
type 2	1
type 5	3

Table II. Radiographic criteria of degenerative changes

Excellent:	Normal radiograph
Good:	Minimal sclerosis
	Minimal joint narrowing
	Minimal spur formation
Fair:	Moderate sclerosis
	Moderate joint narrowing
	Moderate spur formation
	Moderate mottling of the femoral head
Poor:	Any collapse of the femoral head
	Subluxation of the femoral head
	Severe spur formation
	Subchondral cyst formation
	Severe joint narrowing, ankylosis

RESULTS

The functional results in relation to congruency are listed in Table III. Congruency was achieved in 20 patients, all of whom had excellent or good functional results. In three patients congruency could not be achieved; one had sustained a type 5 triradiate cartilage fracture with gross disruption; the second had a comminuted transverse fracture with posterior dislocation of the hip (Figs 1 and 2); and the third patient had a posterior column fracture, which was operated on, but in whom optimal reduction could not be achieved (Figs 3 and 4).

The radiographic results in relation to congruency are shown in Table IV. Good or excellent radiographic results were seen in 16 patients, in all of whom congruency had been achieved. Poor radiographic results were seen in two patients with subluxation of the hip due to type 5 triradiate cartilage fractures and in one patient with severe heterotopic calcification, as seen in Figure 4. Fair radiographic results were seen in four patients: two type 5 triradiate cartilage fractures; one anterior column fracture and one transverse fracture (Figs 1 and 2).

All nerve injuries were transient, except one with persisting peroneal nerve palsy.

Early complications were observed in eight patients: urinary or respiratory infection in four, infection at the traction site in three, and superficial infection at the site of operation in one. All these complications presented no problems in management.

Table III. Functional results in relation to congruency after reduction

	Number	Congruent	Not Congruent
Excellent	19	19	–
Good	2	1	1
Fair	–	–	–
Poor	2	–	2

Table IV. Radiographic results at least three years after injury, in relation to congruency

	Number	Congruent	Not Congruent
Excellent	11	11	–
Good	5	5	–
Fair	4	3	1
Poor	3	1	2

Figs 3 and 4. A 15-year-old boy with a typical posterior column fracture, with central dislocation of the femoral head.
Figure 3 (top): On admission. The femoral head could not be reduced with traction so open reduction and internal fixation was performed, but anatomical reduction was not obtained.
Figure 4 (bottom): Six months after injury there is extensive heterotopic calcification leading to a poor functional and radiographic result. As the hip was painful and almost completely stiff, arthrodesis was performed.

Late complications developed in three patients, all of whom required operative treatment. Two of these patients developed progressive subluxation of the hip after fusion of the triradiate cartilage in type 5 fractures; one had a shelf procedure and the other an intertrochanteric osteotomy in order to obtain better containment of the femoral head. The third patient had a painful, almost ankylosed hip with extensive heterotopic calcification (Fig. 4); this hip was arthrodesed.

DISCUSSION

The primary goal in the management of acetabular fracture-dislocation should be reduction of the femoral head. Many reports have established a relationship between the occurrence of avascular necrosis and a prolonged period of dislocation (Rowe and Lowell 1961). If the reduction is unstable during 0-90° of flexion, in our view operative fixation of the posterior wall fragments should be performed. Recurrent dislocation may be due to a capsular defect, an inverted labrum or interposition of loose osteochondral fragments, and may promote degenerative changes (Canale and King 1984). Both hips should be compared carefully on the post-reduction radiograph, to see if there is any incongruity or difference in the joint space: loose fragments are easily missed on standard radiographs, especially in the young, cartilaginous pelvis. If there is any doubt about completely concentric reduction, arthrography or a CT-scan is indicated. In one of our patients arthrotomy was performed to remove loose osteochondral fragments.

Triradiate cartilage fractures have already been discussed in this journal (Heeg et al. 1988). Although optimal reduction cannot always be achieved by closed means in type 1 and 2 fractures, the functional and radiographic results of conservative treatment are satisfactory. Therefore, primary, operative treatment of these fractures does not seem to be indicated; in any case it is technically extremely difficult, if not impossible. The results of type 5 fractures are less favourable, as fusion of the physis may occur, with the possibility of progressive subluxation of the hip. Secondary reconstructive procedures, such as a shelf operation, Chiari or intertrochanteric osteotomy, may be necessary to obtain containment of the femoral head.

Patients whose fractures were less than 2 mm displaced all had good or excellent functional and radiographic results. An exercise programme should be started in these patients as soon as the initial pain has subsided. Early weight-bearing as advocated by Watts (1976) is, in our view, not indicated because dislocation of the acetabular fragments may occur. In adults better results have been reported when weight-bearing was delayed for three months or longer (Rowe and Lowell 1961; Tile 1980).

Central fracture-dislocation had occurred in three patients. Reduction of the femoral head can sometimes be achieved with combined lateral and longitudinal traction, though penetration of the physis of the trochanter should be avoided. In our patients, however, traction did not result in adequate reduction and all three patients underwent surgery.

Reduction of acetabular fragments may be facilitated by the use of threaded Kirschner wires, which can be removed after six weeks (Watts 1976). Anatomical position was achieved in two patients, using open reduction and internal fixation; this resulted in one fair and one excellent functional result. In the third patient treated operatively, anatomical reduction was not obtained and the result was poor. Fortunately, all three patients had only minor comminuted fractures since, if comminution is severe, the results for both operative and conservative techniques have been reported to be very poor (Canale and King 1984).

The overall functional results (Table III) were better than the radiographic results. This may be because the Harris hip score was not originally developed for children, or because some of the children with radiographic abnormalities have not yet developed functional complaints. Whether these children will remain free of symptoms can only be determined by a follow-up study longer than the average of eight years in our study.

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Chapter 5

Injuries of the acetabular triradiate cartilage and sacroiliac joint

Minne Heeg (1), Jan D. Visser (1), Henk J.M. Oostvogel (2).

(1) Department of Orthopaedic Surgery.
(2) Department of Traumatology.
University Hospital Groningen, The Netherlands.

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SUMMARY

Four patients with injuries of the acetabular triradiate cartilage are presented. In three of them premature fusion of the cartilage occurred; two of these developed acetabular deformity and subluxation of the hip. In all patients the sacroiliac joint also was injured; in two, the joint was completely disrupted, leading to fusion and growth disturbance of the ilium.

As injury of the triradiate cartilage is easily missed on the initial radiograph, it is advised that all patients with pelvic trauma should be followed clinically and radiographically for at least one year.

INTRODUCTION

The acetabular triradiate cartilage is the composite growth-plate of the iliac, ischial and pubic bones. Premature closure of this physis is an infrequent complication of pelvic injury, septic arthritis and pelvic surgery (Rodrigues 1973; Hallel and Salvati 1977; Wientroub, Lloyd-Roberts and Fraser 1981; Bucholz, Ezaki and Ogden 1982). When it occurs in early childhood, disruption of acetabular growth with thickening of the medial acetabular wall and subluxation of the hip may result. Usually the subluxation is mild, the function of the hip is not affected and, during childhood and adolescence, the patient experiences little or no pain. In addition, growth disturbance of the ilium may be caused by premature fusion of the sacroiliac joint (McDonald 1980).

We report four children, each of whom was run over by a truck or bus, injuring the triradiate cartilage and one or other sacroiliac joint, leading to disproportionate pelvic growth. The spectrum of growth disturbances after premature fusion of the triradiate cartilage and fusion of the sacroiliac joint are discussed.

CASE REPORTS

Case 1. A nine-year-old boy had arrived at a local hospital in a state of deep shock. Multiple lesions were diagnosed: a fracture- dislocation of the right hip with a Salter-Harris type V triradiate physeal injury, a right sacroiliac dislocation with lumbar plexus injury, fractures through the pubic and ischial rami and symphysiolysis (Fig. 1). An attempted closed reduction of the dislocated hip was unsuccessful. The pelvis was stabilised with a tension-band wire through the symphysis.

Three weeks after injury the patient was transferred to our hospital where an open reduction was performed. A posterior-rim fracture of the acetabulum was found, as well as multiple osteochondral lesions. Postoperatively the patient was treated in suspended traction, and after six weeks, was mobilised in an Atlanta brace. Two months after injury the right triradiate cartilage had fused (Fig. 2), leading to progressive growth disturbance of the acetabulum. At present six years later, skeletal growth is nearly complete. Fusion of the sacroiliac joint has not occurred and the lumbar plexus injury has recovered spontaneously. There is subluxation of the femoral head and an acetabular shelf has formed, probably caused by fusion of a posterior wall fragment with the acetabulum (Fig. 3). A CT scan (Fig. 4) revealed extensive irregularity and thickening of the medial acetabular wall. The patient is painfree but walks with a severe limp. The right leg is 3 cm shorter than the left with 20° of fixed flexion, 25° of fixed medial rotation and 20° of fixed adduction, for which a corrective intertrochanteric femoral osteotomy is planned.

Case 1.
Figure 1: A fracture-dislocation of the right hip with a type V triradiate physeal injury and dislocation of the sacroiliac joint. Figure 2: Two months after injury there is premature fusion of the right triradiate cartilage with lateralisation of the femoral head. Note also the obvious inefficiency of the tension-band wire. Figure 3: Six years later there is gross deformity as well as extensive irregularity and thickening of the medial acetabular wall. Lateralisation of the femoral head has progressed. Note the spontaneous acetabular shelf formation, and the almost complete fusion of the right triradiate cartilage. Figure 4: A CT scan taken at last review shows extensive irregularity and thickening of the medial acetabular wall.

Fig.1

Fig.2

Fig.3

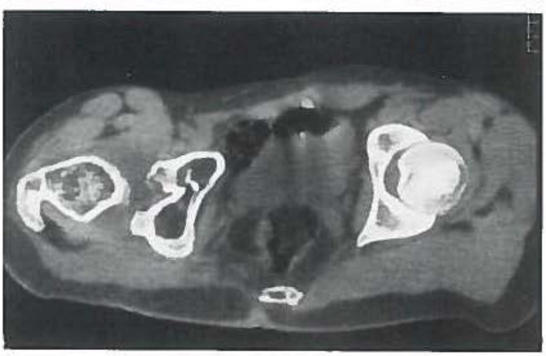

Fig.4

Case 2. A seven-year-old girl had sustained fractures through the right pubic and ischial rami, an anterior dislocation of the left sacroiliac joint, without plexus injury and extensive soft-tissue lesions of both legs (Figs 5 and 6). Open reduction and screw fixation of the superior ramus was performed and the sacroiliac dislocation was reduced. Injury to the triradiate cartilage was not considered. However, one year after the initial injury, a slowly progressive fusion of the right triradiate cartilage was noticed, with thickening of the medial acetabular wall and lateralisation of the femoral head (Figs 7 and 8). Partial fusion of the left sacroiliac joint had led to relative shortening of the ilium (Fig. 7). Four years later, at last review, the patient was painfree, hip mobility was normal except for 10° of limitation of medial rotation, and the leg was 1 cm short. Depending on the rate of progression of the acetabular deformity, a pelvic osteotomy or shelf procedure will be performed. Retrospectively, this was judged to be a type V physeal injury.

Case 2.
Figure 5: A radiograph taken on admission during intravenous pyelography. Fractures through the right pubic and ischial rami are present. Injury of the (right) triradiate cartilage was not considered. Figure 6: Anterior dislocation of the left sacroiliac joint as seen on a CT scan. Figure 7: Four years later there is premature fusion of the right triradiate physis, thickening of the medial acetabular wall and lateralisation of the femoral head. The left sacroiliac joint has fused. Note that the left ilium is short. Figure 8: A CT scan of the acetabular region. Fusion of the right triradiate cartilage has occurred, and the thickening of the medial acetabular wall is clearly visible.

Fig.5

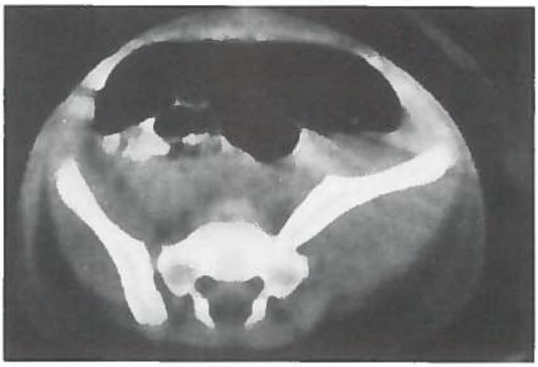

Fig.6

Fig.7

Fig.8

Case 3. A nine-year-old boy had been struck by a bus. Cinical investigation and radiographs revealed a dislocation of the right sacroiliac joint, a lumbar plexus injury and fractures through the left pubic and ischial rami (Fig. 9). Injury of the right triradiate cartilage was not considered at the time of injury, but two months later, premature fusion was noticed; this did not, however, lead to disproportionate pelvic growth (Fig. 10). The patient recovered completely from the plexus injury. At present, eight years later, he has no pain and the function of the hip is completely normal. Retrospectively, this was judged to be a type V physeal injury.

Fig.9

Fig.10

Case 3.
Figure 9: A radiograph taken on admission shows displacement at the right sacroiliac joint and fractures through the left pubic and ischial rami. Injury of the triradiate cartilage was not considered. Figure 10: Two months later premature fusion of the right triradiate cartilage was observed. However, further pelvic deformity did not occur.

Case 4. A two-year-old girl had sustained severe disruption of the left hemipelvis with a dislocation of the sacroiliac joint, symphysiolysis, a type I triradiate physeal injury, extensive genito-urinary injuries and soft-tissue lesions of the legs (Fig. 11). A laparotomy was performed to repair the genito-urinary lesions and to stabilise the pelvis using a tension-band wire. During follow-up, disproportionate pelvic growth was observed, with fusion of the left sacroiliac joint and shortening of the pelvic bones (Fig. 12). The acetabulum developed normally. Now, 19 years later, she is painfree and has normal hip function, although there is a leg-length inequality of 2 cm.

Fig. 11

Fig. 12

Case 4.
Figure 11: In this radiograph, taken on admission, the left hemipelvis is displaced upwards and the left sacroiliac joint is grossly disrupted. A type I triradiate physeal injury can be seen. The ischiopubic fragment is rotated. Figure 12: The resulting pelvic deformity 19 years later: the left sacroiliac joint fused, with shortening of the ilium. The pubic and ischial bones are still rotated and shortened. The acetabulum had developed normally.

DISCUSSION

The large acetabular cartilage complex is composed of a hemispherical cup-shaped cartilage and the triradiate cartilage; the former fills the outer two-thirds of the acetabular socket and is continuous with the triradiate cartilage medially (Fig. 13). The physis within the cartilage is bipolar and its intrapelvic side is covered by perichondrium and thick fibrous tissue (Ponseti 1987).

Three of the many secondary centres of ossification which develop in the pelvis appear after the age of eight years in the cartilage surrounding the acetabular cavity: the iliac and pubic centres of ossification constitute major portions of the superior and anterior wall of the acetabulum (Fig. 13); the ischial centre is very small and rarely seen (Ponseti 1978). Growth of the acetabulum and pelvic bones is very complicated: interstitial growth within the triradiate cartilage is responsible for the growth in height and width of the acetabulum and also contributes to growth in length of the pelvic bones. The depth of the acetabulum increases during development as a result of the interstitial growth in the hemispherical cartilage and of appositional growth of the periphery of this cartilage (Ponseti 1978). The concavity of the acetabulum develops in response to the presence of a spherical head.

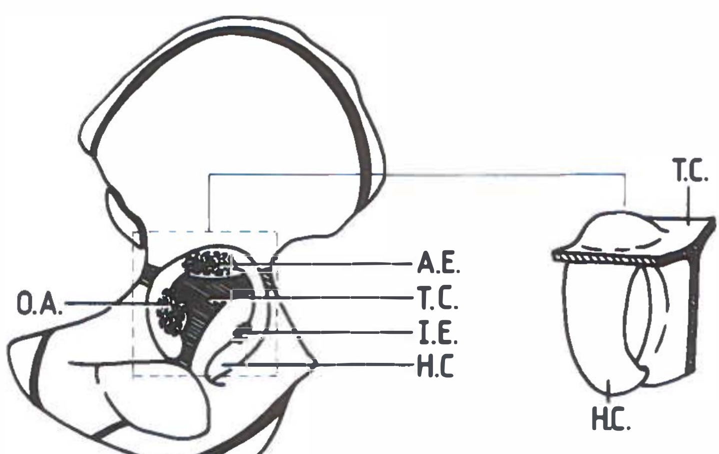

Fig. 13: A diagram of the left innominate bone (left) and an oblique schematic view demonstrating the continuity of the hemispherical and triradiate cartilages (right). The acetabular cartilage complex is composed of a hemispherical cartilage (HC) and triradiate cartilage (TC). Three secondary centres of ossification appear in the cartilage surrounding the acetabular cavity: the os acetabuli (OA) of the pubis, the acetabular epiphysis (AE) of the ilium and the ischial epiphysis (IE). (Figures modified from Ponseti, 1978 [left] and Bucholz et al, 1982 [right]).

Growth in the height and width of the ilium, ischium and pubis is essentially like growth in tubular bones: the physeal plates at the ends are responsible for growth in length, the periosteum for growth in width (Ponseti 1978). The general effect of trauma on the epiphysis and growth-plate has been described by Siffert (1977). Acute trauma to a portion or to the entire plate which destroys the germinal cell layer or its vascularity results in partial or total growth arrest. When only a portion of the plate is damaged, the unaffected segment continues to grow. The progressive deformity that may occur depends on the future growth potential of the unaffected segment of growth cartilage: the younger the patient, the longer the period of growth and the greater the possible deformity. However, why the deformity occurs in some patients with triradiate cartilage injury while not in others is still not clearly understood. A type V physeal injury was always associated with deformity in the series of Bucholz et al. (1982), as well as in two of our patients (Cases 1 and 2), but in Case 3 there was no progressive deformity.

The patient's age at the time of injury is important: severe deformity has not been described with injury after the age of 11 years (Bucholz et al. 1982). Experimental investigation in the rabbit has demonstrated that selective fusion of all three limbs of the triradiate cartilage or fusion of only the ilioischial limb caused acetabular dysplasia; this was associated in 50% with dislocation of the hip. Iliopubic fusion had only a minimal effect on acetabular development (Gepstein, Weiss and Hallel 1984). This may be explained by the predominance of the ilioischial limb, which is twice the size of the iliopubic limb. Injury of the triradiate cartilage can be easily missed at the initial radiographical examination. In two of our patients (Cases 2 and 3) the diagnosis could not be made on the initial radiograph, and only retrospectively was it ascertained that both had sustained a type V physeal injury.

If traumatic fusion of the triradiate cartilage occurs without damage to the hemispherical cartilage, the latter continues to grow and eventually displaces the acetabulum laterally. This creates the typical thickening of the acetabular wall. Damage to the metaphysis adjacent to the growth-plates may inhibit the growth in length of the pelvic bones (Ponseti 1978).

Injury of the sacroiliac joint may cause fusion, leading to a shorter ilium (McDonald 1980) this occurred in two of our patients (Cases 2 and 4). In the remaining two patients only minor sacroiliac displacement occurred and there was no growth disturbance.

The general management of triradiate cartilage injuries should not differ from that of other pelvic fractures. Theoretically, any subsequent osseous bridging can be resected and replaced by fat, but the surgical difficulties encountered with this procedure limit its practical use (Langenskiöld 1975). When subluxation is severe and the patient is symptomatic, a pelvic osteotomy may be necessary. However, there are very few reports on this in the literature. Blair and Hanson (1979) reported treating such a patient with a Chiari osteotomy, but the result was not recorded. It is important to perform clinical and radiographical follow-up examinations for a period of at least one year in order to detect a post-traumatic deformity at its earliest stage.

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Chapter 6

Conservative treatment of acetabular fractures: the role of the weight-bearing dome and anatomic reduction in the ultimate results

Minne Heeg (1), Henk J.M. Oostvogel (2) and Henk J. Klasen (2).

(1) Department of Orthopaedic Surgery
(2) Department of Traumatology
University Hospital Groningen, The Netherlands.

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SUMMARY

A retrospective study of 57 conservatively treated acetabular fractures with an average follow-up of 7.9 years is presented. The overall functional result was satisfactory in 75%. The least satisfactory results were seen in fractures crossing the weight-bearing dome of the acetabulum in which congruency could not be achieved (N=11, nine patients had fair or poor results). However, fractures crossing the weight-bearing dome which could be reduced by traction to less than 2 mm (N=8) gave good or excellent results in seven patients. It is concluded that conservative treatment of acetabular fractures can be very successful, even in fractures crossing the weight-bearing dome, provided that congruence is preserved during the period of traction.

INTRODUCTION

Acetabular fractures are relatively uncommon. It will therefore be difficult for the average surgeon to obtain a wide experience in their treatment. The treatment of choice in the past decades was skeletal traction. Sometimes additional manipulation or immobilization in a plaster cast was used. As in all weight-bearing joints, one of the most common late effects is degenerative arthritis. Insufficient reduction of displaced fractures and severe osteochondral lesions are thought to play a major role in the origin of this complication [5]. For this reason Letournel and Judet proposed open reduction and internal fixation for all displaced acetabular fractures [6]. But, besides the fact that operative management of acetabular fractures is technically difficult, the operation carries its own risks, such as infection, heterotopic calcification and sciatic nerve injuries.

Recent literature has focused on the importance of the involvement of the weight-bearing dome as a prognostic factor in the ultimate result of treatment [2,7,8,11]. If displaced fractures of the weight-bearing dome (W.B.D.) are not reduced sufficiently, the ultimate result of treatment will be poor, no matter which treatment has been applied.

The purpose of this retrospective analysis of the results of nonoperative treatment of acetabular fractures was to evaluate the role of the weight-bearing dome, and the influence of the amount of displacement between the femoral head and the acetabulum in the ultimate results.

MATERIALS AND METHODS

This retrospective study involves data from the period 1972 through 1981. During this period 135 patients with acetabular fractures were treated at the department of Traumatology at the University Hospital in Groningen. Of these patients, 85 were treated nonoperatively and 50 operatively. From the 85 patients treated conservatively, 16 were found to have died and 13 could not be traced.

Therefore 56 patients with 57 fractures of the acetabulum were available for follow-up. The average period of follow-up was 7.9 years, ranging from 4-12 years. Of these patients 38 were male and 18 female. The average age at the time of the accident was 37 years, ranging from 18-60 years. Thirty-three fractures involved the right hip and 24 the left. Forty-nine (88%) of the injuries were due to traffic accidents. Thirty-one of the patients had an Injury Severity Score of 18 or more, which indicates a high degree of associated injuries. Five patients suffered from a primary nerve injury: transient peroneal nerve palsy occurred in two cases and a lumbar plexus lesion in combination with a sacro-ileal dislocation in three cases. Ten patients had an additional dislocation of the femoral head: nine had a posterior dislocation and one had a dislocation of the central type. In all these cases reduction was performed under general anesthesia within 24 hours of the accident. Indications for conservative treatment were:

1) successful closed reduction of the femoral head, which could be maintained during the period of traction, without sciatic nerve injury;

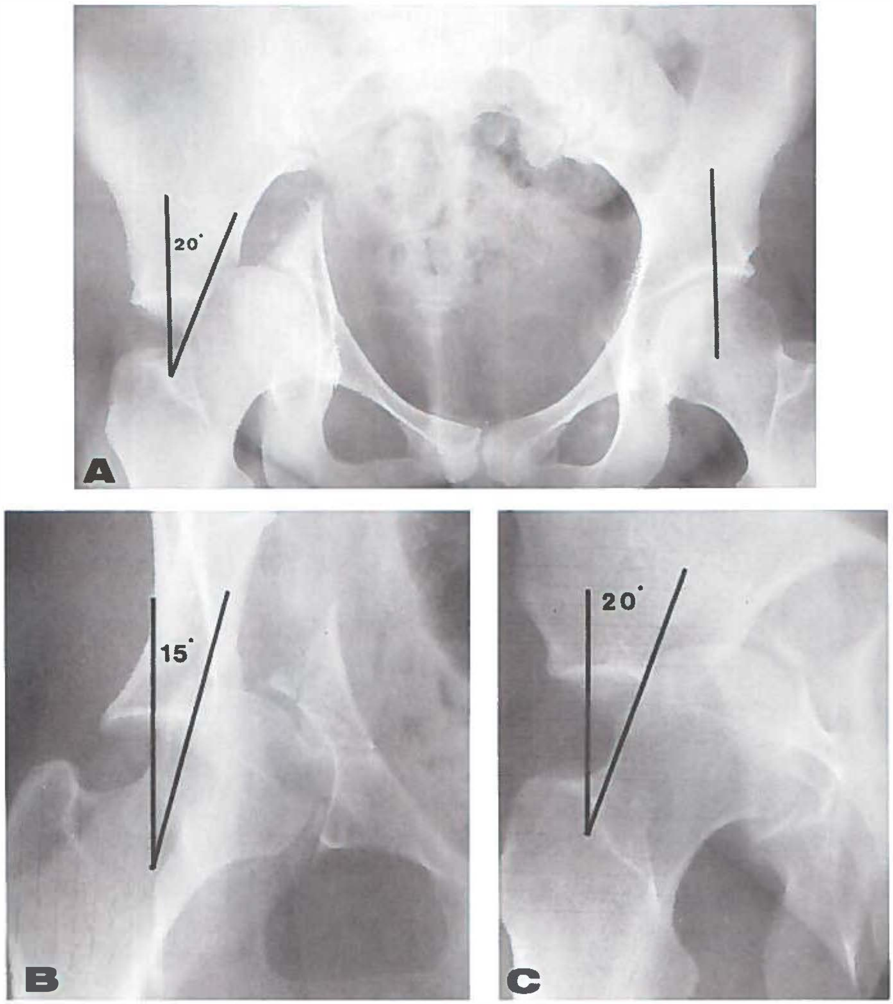
2) patients with severe comminution, without sciatic nerve injury, in whom it was assumed that an operation could not improve the fracture reduction;
3) poor general condition of the patient which did not permit surgery.

Conservative treatment consisted of supracondylar or tibial traction. Eight patients were treated with bed rest only, without traction for various reasons such as: contaminated wounds and concomitant fractures of the affected leg. The average skeletal-traction period was 5.9 weeks (range: 0-14 weeks). Traction was followed by progressive weight-bearing. The average interval between the accident and full weight-bearing was 4.9 months (range: 2-12 months).

TABLE I
Fracture classification according to Letournel and Judet

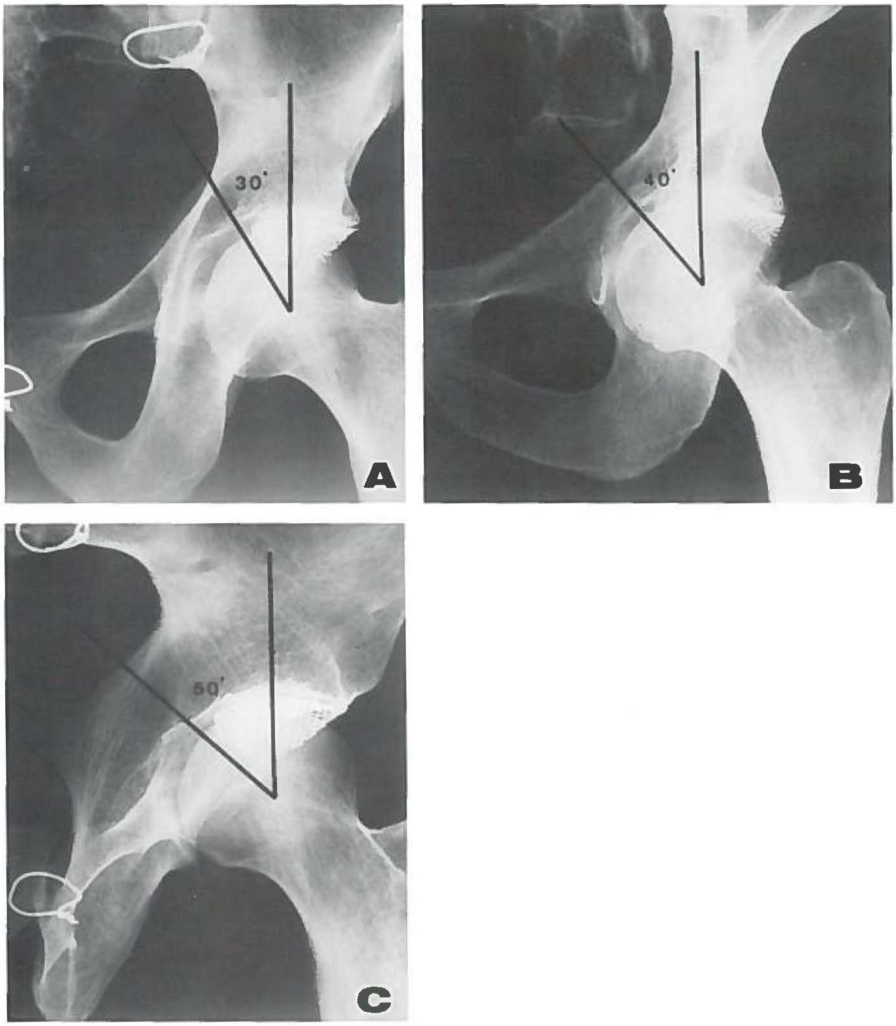
Fracture Type	Number
Posterior wall	12
Posterior column	5
Anterior wall	1
Anterior column	7
Transverse	16
T-shaped	1
Post. column and post. wall	0
Transverse and post. wall	7
Anterior wall and post. column	1
Both columns	7
Total	57

The fractures were classified according to Letournel and Judet (6) into elementary (N=41) and associated types (N=16) (Table I). The weight-bearing dome was evaluated in two ways. First the W.B.D. was quantified according to Matta, using three so-called roof arc measurements [7,8] (Figs 1A, 1B & 1C). The medial roof arc was measured on the antero-posterior radiograph. A vertical line was drawn to the geometric center of the acetabulum. Another line was drawn from the point where the fracture line broke the roof to the same geometric center. The angle formed is called the medial roof arc. Similar angles were calculated on the iliac oblique view (posterior roof arc) and obturator oblique view (anterior roof arc). In the presence of an adequate W.B.D., the anterior roof arc constitutes an angle of $\geq 40°$, the medial roof arc of $\geq 30°$, and the posterior roof arc of $\geq 50°$.



Figs 1A, 1B and 1C. Roof arc measurements to evaluate the weight- bearing dome. This patient sustained a high transverse acetabular fracture through the weight-bearing dome.
Fig. 1A: Anteroposterior view: medial roof arc of 20°; Fig. 1B: Obturator oblique view: anterior roof arc of 15°; Fig. 1C: Iliac oblique view: posterior roof arc of 20°.

In addition to the roof arc measurements, the W.B.D. of a skeleton was marked with lead wire and standard radiographs were taken (Figs 2A, 2B, & 2C). This model gave more insight in the three-dimensional structure of the W.B.D. With the aid of these radiographs and the roof arc measurements, the involvement of the W.B.D. could be determined.



Figs 2A, 2B and 2C. The weight-bearing dome of a skeleton model marked by lead wire. In addition, the roof arcs in case of an adequate dome are marked. Fig. 2A: anteroposterior view: medial roof arc of ≥30°; Fig. 2B: obturator oblique view: anterior roof arc of ≥40°; Fig. 2C: iliac oblique view: posterior roof arc of ≥50°.

Displacement was measured on all radiographs. A displacement of 2 mm or less was considered to be congruent.

The follow-up examination consisted of a physical and a radiologic part (A.P. pelvic view, obturator, and iliac oblique views). The functional result was evaluated according to the Harris hip score, in which pain, function, absence of deformity, and range of motion are given with a maximum of 100 points [3]. The result was classified as excellent with a score of 91-100 points, good 81-90, fair 71-80, and poor with ≤ 70 points. The criteria for degenerative radiological changes are shown in Table II.

TABLE II
Radiologic criteria for degenerative changes

Excellent:	Normal radiograph
Good:	Minimal sclerosis
	Minimal joint narrowing
	Minimal spur formation
Fair:	Moderate sclerosis
	Moderate joint narrowing
	Moderate spur formation
	Moderate mottling of the femoral head
Poor:	Any collapse of the femoral head
	Subluxation of the femoral head
	Severe spur formation
	Subchondral cyst formation
	Severe joint narrowing, ankylosis

RESULTS

The functional results in relation to congruency and involvement of the W.B.D. are listed in Table III. In 43 patients the functional results could be classified as excellent or good.

In 46 patients the hip joint was congruent: in 41 of these 46 patients the result was excellent or good. In 11 patients congruency could not be achieved. In all these patients the fracture line crossed the weight-bearing dome. Only two of these 11 patients had good or excellent functional results: one had sustained a pure transverse fracture and the other had a both columns fracture. The nine fair and poor functional results in this category concerned all fractures with involvement of the posterior wall and/or posterior column (Figs 3A & 3B).

In Table III the influence of the involvement of the W.B.D. on the ultimate functional result is also presented. Eleven patients were excluded because the fracture was confined to the rim of the posterior wall of the acetabulum. These fractures were always classified as congruent. In the remaining 46 fractures, 19 crossed the W.B.D. and 27 did not. Of the 19 patients in whom the W.B.D. was involved, nine had excellent functional results. Of the 27 patients in whom the W.B.D. was not involved, 24 had excellent or good functional results.

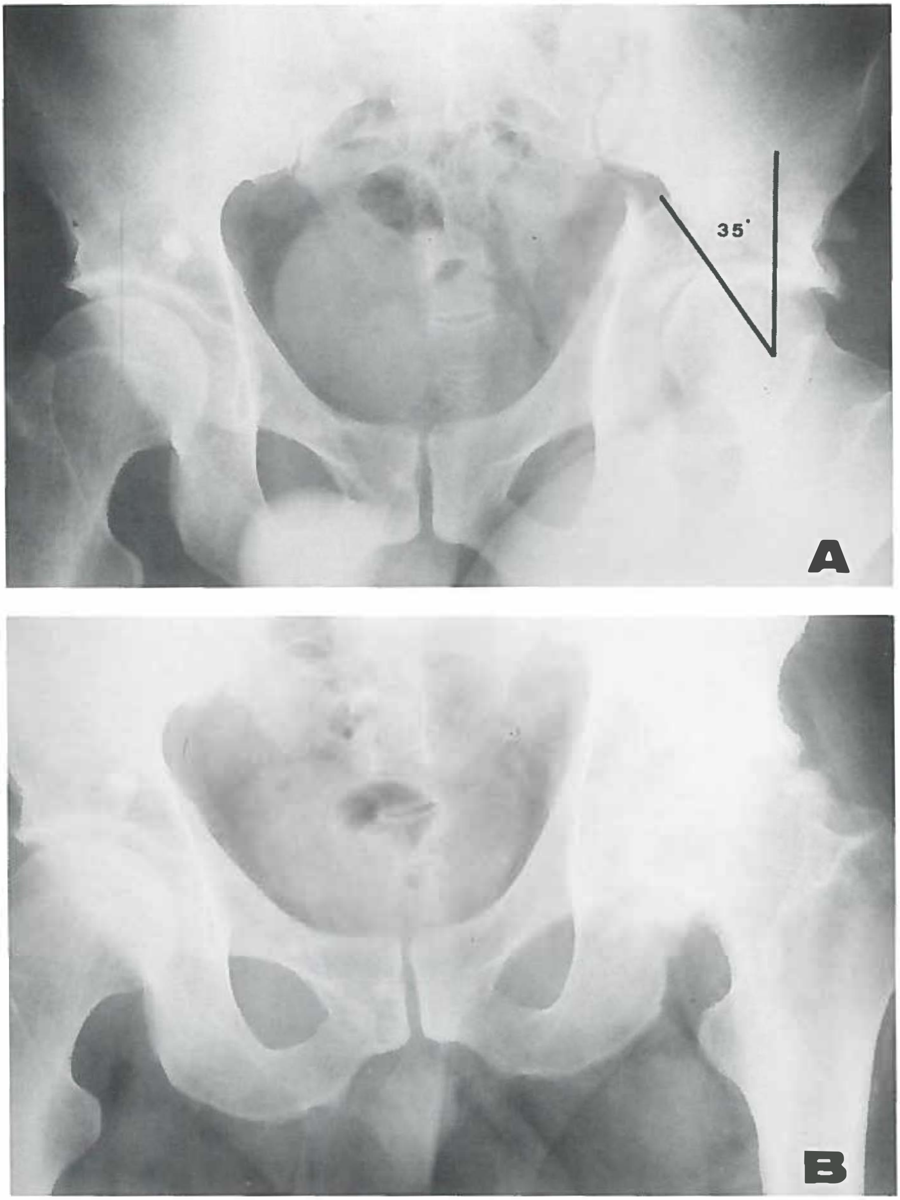


Fig. 3A: A patient with a high transverse and posterior wall fracture through the weight-bearing dome. Congruency could not be achieved. Fig. 3B: The result 5 years later: the patient had a poor radiologic and functional result.

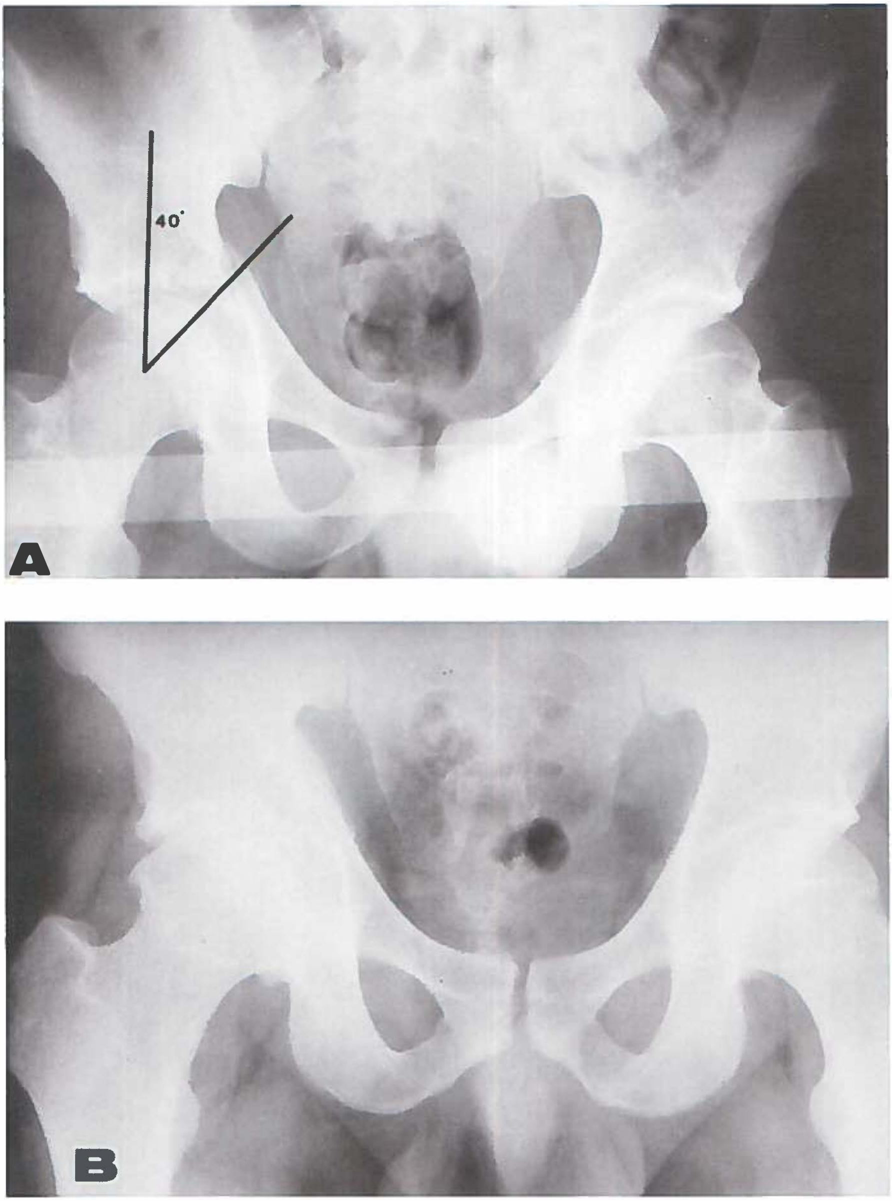


Fig. 4A: A patient with a pure transverse fracture through the weight-bearing dome. The medial roof arc was 40°, but the posterior roof arc was 30°. Congruency could not be achieved. Fig. 4B: The result 3 years later: an excellent radiologic and functional result.

TABLE III
Overall functional results (according to the Harris hip score) in relation to congruency and involvement of the weight-bearing dome

Results	Total	Congruency		W.B.D. Involved	
		Yes	No	Yes	No
	N=57	46	11	19	27
Excellent	40	38	2	9	22
Good	3	3	–	–	2
Fair	5	3	2	3	2
Poor	9	2	7	7	1

TABLE IV
Relationship between the radiologic results, the congruency, and the weight-bearing dome

Results	Total	Congruency		W.B.D. Involved	
		Yes	No	Yes	No
	N=57	46	11	19	27
Excellent	40	40	–	11	22
Good	11	6	5	2	5
Fair	3	–	3	3	–
Poor	3	–	3	3	–

The results of the fractures crossing the W.B.D. in which congruency was not achieved are mentioned above (11 patients, of whom nine had fair or poor results). Much better results were seen in fractures crossing the W.B.D. where congruency between the femoral head and the acetabulum had been achieved: seven out of these eight patients had excellent or good results (these results are not listed in Table III) (Figs 4A & 4B).

The relationships between the radiologic results, congruency, and the involvement of the W.B.D. are presented in Table IV. In cases where joint congruency was achieved, or the fractures did not cross the W.B.D., excellent or good radiologic results were seen in all patients. Fair or poor radiologic results were noted in six of the 11 fractures in which congruency was not achieved, and in six of the 19 fractures crossing the W.B.D. Complications occurred in 11 patients: in seven patients a urinary or respiratory infection developed, in three patients infection of the traction site occurred, and one patient had to be treated for lung embolism in spite of anticoagulant prophylaxis. Two patients suffered from such a degree of coxarthrosis that total-hip arthroplasty was performed 2 and 4 years after the accident.

DISCUSSION

The primary goal in the management of acetabular fracture/dislocation should be the reduction of the dislocation of the femoral head, if present. In many reports the relationship between the occurrence of avascular necrosis and a prolonged period of dislocation has been demonstrated [1,5,9,10].

In recent literature there appears to be consensus on the fact that the next step in the treatment should be adequate fracture reduction, operative or nonoperative, and the re-establishment of the weight-bearing dome [2,7-10]. The concept of the weight- bearing (or superior) dome has been mentioned by many authors [2,9-11]. However, it appears that it is very difficult to define.

In our material the evaluation of the W.B.D. was performed with a skeleton model and the roof arc measurements according to Matta. It must be pointed out that this measurement is a simplification of the real W.B.D. because the three-dimensional structure of the W.B.D. cannot easily be identified with anatomical land-marks on standard radiographs. The roof arc measurements are sufficient to decide whether or not the W.B.D. is crossed by fracture lines. In seven of the eight patients in whom the W.B.D. was involved but complete joint congruence could be achieved, the ultimate functional results were excellent or good. When only the congruency between the femoral head and acetabulum was examined, we found that in 46 fractures it had been possible to achieve congruency by closed means. This led to excellent or good functional results in 41 of these patients, whereas this was only the case in two of the 11 patients in whom congruency was insufficient.

The radiologic results (Table IV) show that the fractures crossing the W.B.D. gave less favourable results compared to fractures that did not involve the W.B.D. The same applies to fractures in which congruency could not be achieved in comparison to congruent fractures. These findings confirm reports correlating good or excellent results with anatomic reduction and the noninvolvement of the W.B.D. [2,4,5,7,8]. Our findings suggest that although both factors have a strong influence on the ultimate result, joint congruence is the most important factor.

Some fracture types are more liable to give satisfactory results after conservative treatment than others. Patients with low anterior column fractures, low transverse fractures, both columns fractures without posterior displacement or, fractures with a displacement of 2 mm or less after traction are good candidates for conservative treatment. On the other hand, open reduction and internal fixation should be considered in posterior wall, high transverse or T-shaped fractures and when there is interpositioning of bone or soft-tissue. In 14 patients with a fair or poor result, 12 patients had the latter types of fracture.

CONCLUSIONS

Acetabular fractures can be treated by nonoperative means with good results, if joint congruence can be achieved. Even with violation of the weight-bearing dome, conservative treatment can be very successful, provided that congruence is preserved during the period of traction. If congruence is not achieved, especially in the weight-bearing dome, the prognosis is very poor and operative reduction and internal fixation should be considered.

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Chapter 7

Operative treatment for acetabular fractures

Minne Heeg (1), Henk J. Klasen (2) and Jan D. Visser (1).

(1) Department of Orthopaedic Surgery.
(2) Department of Traumatology.
University Hospital Groningen, The Netherlands.

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SUMMARY

We report a retrospective study of 54 acetabular fractures treated by open reduction and internal fixation, with an average follow-up of 9.6 years (3 to 17). Reduction leaving displacement of $\leqslant$ 2 mm was achieved in 36 hips (67%); good or excellent functional results were obtained in 33 patients (61%).

Early complications requiring reoperation included postoperative loss of reduction in one case and an intra- articular screw in another. Arthrodesis or total hip arthroplasty had been performed in 10 patients (19%) who had late symptomatic degenerative changes. Failure to obtain accurate reduction was the most important factor leading to a poor result, but heterotopic calcification caused poor results in seven patients, five of whom had had an anatomical reduction.

INTRODUCTION

The treatment of acetabular fractures remains controversial. Conservative treatment can be very successful, even for fractures through the weight-bearing dome, provided that congruency is achieved and maintained with traction. If congruency is not achieved, a poor prognosis may be expected and operative treatment is indicated (Heeg, Oostvogel and Klasen 1987). Open reduction and internal fixation has been proposed for all displaced acetabular fractures, assuming that late degenerative changes will be decreased by anatomical reduction of the articular surface (Letournel and Judet 1981). Because of unsatisfactory results with both conservative and operative treatment of certain fracture types, even primary total arthroplasty has been recommended (Ulrich, Burri and Neugebauer 1986).

Thus, there are conflicting opinions on the preferred treatment for a given case. Although this is partly a reflection of the highly variable characteristics of the fracture itself, there is a need for long-term follow-up studies. The purpose of our retrospective study was to evaluate the long-term results of operative treatment in patients of 18 years or older. We have already reported our results in younger patients (Heeg, Klasen and Visser 1989).

PATIENTS AND METHODS

From 1971 to 1985, we treated 56 patients with acetabular fractures by open reduction and internal fixation, and were able to examine 51 of them at follow-up. We also include the (poor) end results of three patients who died from unrelated causes. During the same period 102 fractures of the acetabulum were treated conservatively.

Of the 54 patients included, 44 were men and 10 women; the left hip was affected in 33 cases, the right in 21. The average age of the patients at the time of injury was 34 years (range 18 to 67). Fifty-two injuries resulted from high-energy traffic accidents and two from falls. Fifteen patients had associated fractures of the lower limb; five of these involved the femoral head and two the femoral neck. Eleven patients suffered a primary nerve injury: the sciatic nerve was damaged in six, the peroneal nerve in four and there was one lumbosacral plexus injury.

TABLE I.
Types of acetabular fracture treated by operation.

	Number
Posterior wall	24
Posterior column	3
Anterior column	3
Transverse	6
T-shaped	3
Transverse and posterior wall	10
Both columns	5
Total	54

The fractures were classified according to Letournel and Judet (1981), Table I. In 31 patients a posterior dislocation of the hip was present: all these were reduced under general anaesthesia within 24 hours. There was central dislocation of the hip in 14 patients; they were treated primarily with longitudinal, lateral or combined traction.

INDICATIONS.

Our indications for open reduction and internal fixation were:

1) unstable posterior fracture-dislocation, 2) inadequate reduction of the femoral head by traction, 3) residual displacement of the weight-bearing dome, and 4) persistent sciatic nerve palsy despite closed reduction.

TREATMENT.

If there was an unstable pelvic disruption, the pelvis was stabilised. Unstable posterior fracture-dislocations were operated on within 48 hours; for other types of fracture, surgery was postponed until the patient was stabilised, but usually took place within five days. In eight patients with multiple life-threatening disorders, surgery was postponed for four weeks after injury.

Depending on the fracture type, either a posterior (Kocher- Langenbeck) or an iliofemoral approach was used. In four patients with femoral head fractures, a small fragment of the head was removed; in one patient internal fixation was performed. Fixation of the acetabulum was either with compression screws alone, or in combination with a neutralisation plate. Postoperatively, the patient was treated in suspended traction for 6 to 8 weeks, and then allowed partial weight-bearing. Full weight-bearing was allowed after 12 to 16 weeks.

ASSESSMENT.

Follow-up examination was performed at an average of 9.6 years (range 3 to 17) and included radiography. We considered residual postoperative displacement of 2 mm or less as congruent. The functional result was evaluated by the Harris hip score (Harris 1969). The criteria for degenerative radiographic changes are shown in Table II. The Brooker classification of heterotopic calcification was used: grade 0, no ectopic bone; grade I, small islands of bone; grade II, at least 1 cm between opposing surfaces of bone; grade III, less than 1 cm between opposing surfaces; and grade IV, apparent ankylosis (Brooker et al 1973).

Table II.
Radiographic criteria used to assess degenerative changes.

Grade	Findings
Excellent	Normal radiograph
Good	Minimal sclerosis
	Minimal joint narrowing
	Minimal spur formation
Fair	Moderate sclerosis
	Moderate joint narrowing
	Moderate spur formation
	Moderate mottling of femoral head
Poor	Any collapse of femoral head
	Subluxation of femoral head
	Severe spur formation
	Subchondral cyst formation
	Severe joint narrowing or ankylosis

RESULTS

CONGRUENCY.

Congruency was achieved in 36 patients (67%), and 18 had a residual displacement of between 2 mm and 5 mm. The failure to obtain congruency could be attributed to the severity of osteochondral damage in eight patients, to extensive callus formation in eight patients in whom operation was postponed to the fourth week and to inadequate exposure in two patients with fractures of both columns. Fractures of both columns were the most difficult to reduce.

FUNCTIONAL RESULTS.

Of the 36 patients with congruent reductions, 31 achieved good or excellent functional results (Figs 1 and 2, Table III). The five patients with poor results despite adequate reduction had grade III or IV heterotopic calcification which caused functional impairment (Figs 3 and 4). Seven patients who had been asymptomatic two years after injury, were found to have functional complaints at later follow-up.

RADIOGRAPHIC RESULTS.

Good or excellent radiographic results were obtained in 27 patients, in all of whom congruity had been achieved (Table IV). Six patients had avascular necrosis of the femoral head: four segmental necrosis and two with total head necrosis. Three of these six patients had poor results, the other three had minor complaints only. The incidence of avascular necrosis could not be related to the type of fracture.

TABLE III.
Functional results related to congruency after reduction.

Result	Number	Congruent	Not congruent
Excellent	26	25	1
Good	7	6	1
Fair	4	–	4
Poor	17	5	12

TABLE IV.
Radiographic results related to congruency after reduction.

Result	Number	Congruent	Not congruent
Excellent	22	22	–
Good	5	5	–
Fair	8	4	4
Poor	19	5	14

HETEROTOPIC CALCIFICATION.

No heterotopic calcification was seen in 27 patients, but 10 had grade I, eight had grade II, six grade III and three grade IV. Heterotopic calcification did not increase after 16 months in any patient. Seven of the nine patients with grade III or IV calcification had limited hip function; in five of these, reduction had been anatomical. We could find no correlation between the grade of heterotopic calcification, femoral head injury, surgical approach, or the timing of operation. Indomethacin had rarely been used as an analgesic, so could not be related to calcification.

COMPLICATIONS.

Twelve patients had early complications: six with urinary or respiratory tract infection; three with deep venous thrombosis or pulmonary embolism, despite anticoagulant therapy; and one with a wound infection. None of these complications presented management problems.

Two patients required reoperation within 48 hours: one had an intra-articular screw removed, and the other, with fracture of both columns, needed more fixation for loss of reduction.

Late reoperation was necessary in 10 patients with symptomatic degenerative changes. Five had this within one year: three with fractures of both acetabulum and femoral head had total hip arthroplasties and two with painful heterotopic calcification had arthrodesis. In the other five patients, total hip arthroplasty was performed 8 to 12 years after the original injury.

NERVE INJURY.

Five of the 11 patients with a primary nerve injury failed to recover completely, three of them having extensive functional impairment.

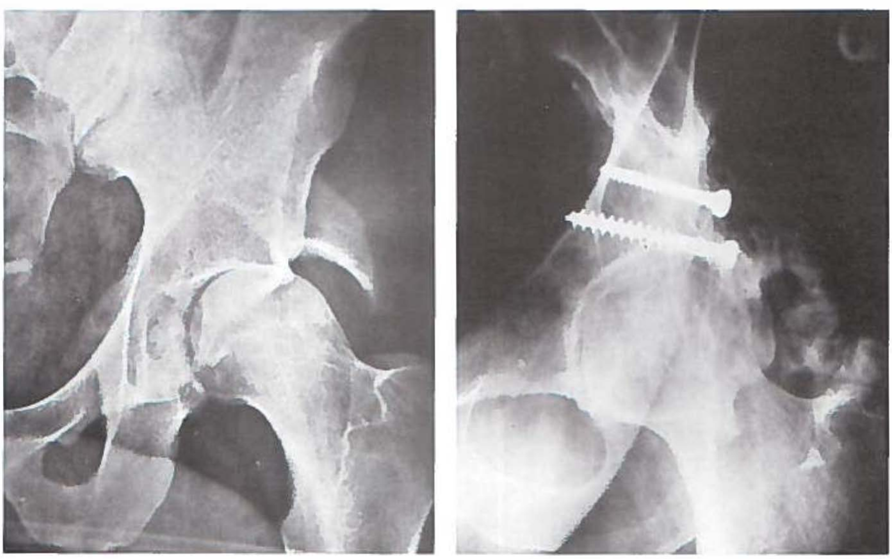

Figure 1 (left). Posterior fracture-dislocation of the hip, with a transverse acetabular fracture, and a rim fracture of the posterior wall. There is minimal comminution. After reduction of the dislocation, the hip was stable, but the weight-bearing dome could not be reduced on traction. Figure 2 (right). Eight years after open reduction and internal fixation there was an excellent clinical and radiographical result.

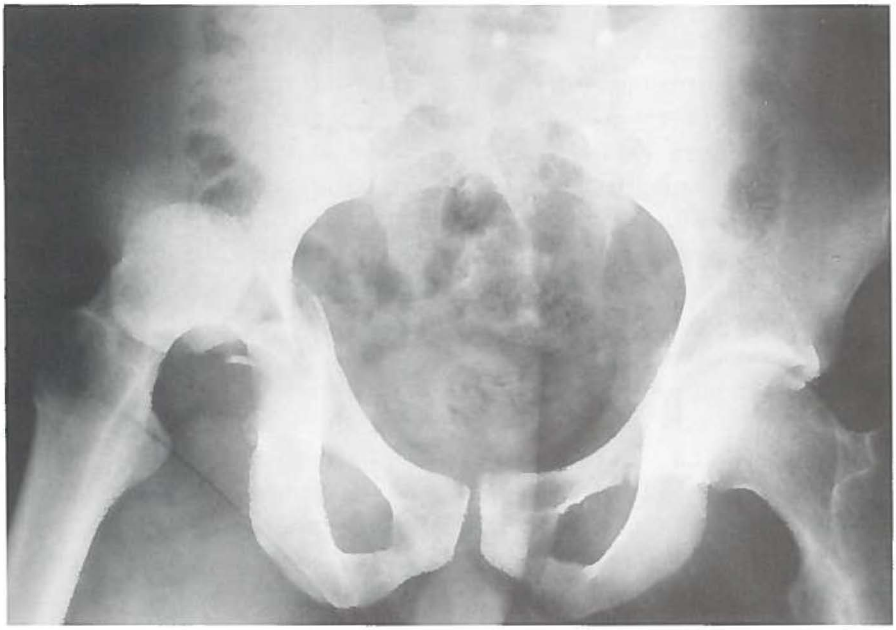

Figure 3 (top). An unstable posterior wall fracture. Figure 4 (bottom). Two years after open reduction and internal fixation. There is minimal slcerosis and joint narrowing but the patient had severe limitation of hip function caused by grade III heterotopic calcification.

DISCUSSION

The operative treatment of displaced acetabular fractures has progressed enormously over the past decades. There have been improvements in clinical and radiographic evaluation, fracture classification, surgical approaches, and reduction and fixation techniques. The aim of treatment is to obtain stable internal fixation with anatomical restoration of the articular surface, especially in the weight-bearing area. It is not yet certain whether the onset of post-traumatic degenerative change is reduced by anatomical reduction. The comparison of operative and conservative treatment is very difficult because so many variables are involved.

The indications for surgery we used are widely accepted (Lansinger 1977; Tile 1980). However, it is still open to debate whether residual displacement of the medial acetabular wall requires operation, even when the femoral head is reduced; excellent results have been reported with conservative treatment (Tipton, D'Ambrosia and Ryle 1975). When operative treatment is being considered for this type of fracture, the risks of infection, sciatic nerve injury and heterotopic calcification should be kept in mind.

The end result of primary open reduction and internal fixation correlates with the quality of the reduction obtained. Failure to obtain congruency was the major factor related to our poor results (Table V). In view of the poor results we obtained in patients operated on three to four weeks after injury, we now favour a conservative approach when early operation is not possible.

Extensive osteochondral damage also led to poor results. Pre-operative CT scans were not available for most of our patients, but may have provided important information on the extent of damage. Again, our poor results for this group lead us to advocate a conservative approach.

Posterior fracture-dislocation of the hip with fracture of the femoral head or neck is a surgical emergency. Small head fragments can safely be removed (Epstein, Wiss and Cozen 1985), and the long-term prognosis is probably related to the extent of the initial osteochondral damage.

The most common complication in our series was heterotopic calcification. An increased incidence is reported after surgery; this and its severity vary with the approach, the use of osteotomies, the amount of subperiosteal stripping and the severity of the fracture (Bosse et al 1988). Though five of our patients had a poor result caused by extensive calcification, it should be emphasised that grade III calcification may be compatible with an excellent result. Postoperative low-dose irradiation has been recommended but is not without risk (Bosse et al 1988).

Our results for operative treatment are comparable to those from other large series (Mommsen, Jungbluth and Thiessen 1985). If operative treatment is indicated and performed, every effort must be made to obtain congruency, since this seems to be the major factor in satisfactory long-term results. Careful pre- operative analysis of both fracture and patient, and accurate planning and surgical technique are essential, but demanding. Even when congruency is obtained, the end result may be spoilt by extensive heterotopic calcification. Five of our patients required total hip arthroplasty after 8 to 12 years, so it is clear that prolonged follow-up is necessary. In this respect, reports of the promising results of operative treatment based on follow-up at one to two years are of limited value.

TABLE V.
Factors related to poor functional results. Each patient may have one or more factors.

	Number of patients
Failure to obtain congruency	
Late operation (over 3 weeks)	8
Extensive osteochondral damage	8
Inadequate exposure	2
Heterotopic calcification	7
Femoral head or neck fracture	4
Avascular necrosis of femoral head	3
Primary nerve injury	3
Intra-articular screw	1

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Chapter 8

Summary and conclusions

SUMMARY

As fractures of the acetabulum are rare, the individual surgeon is frequently unable to obtain wide experience with their treatment. Conservative treatment with skeletal traction has been used for decades, with varying degrees of long-term success. Since the 1950s, the principles of open reduction and stable internal fixation with restoration of the articular surface, have been applied to the treatment of acetabular fractures. Several new surgical approaches, reduction and fixation techniques were invented. The long-term results and complications of these, often formidable, surgical interventions have not been clearly established. As inconstant results of both conservative and operative treatment have been reported, the choice of a specific treatment in a patient with a certain type of fracture is not an easy task. In order to make this choice possible, the long-term results and the factors which seem to influence these results in both modes of treatment were determined in a retrospective study. Particular attention was focused on acetabular fractures in children; specifically fractures through the physis of the acetabulum, as very little is known about the long-term results of these fractures in general.

In Chapter 2, the radiography of acetabular fractures is discussed. Radiographic analysis is an essential tool in the decision-making proces. Routine radiographic investigation, which must be performed in every patient, includes an anteroposterior and two oblique views. Additional important information may be obtained from multi-level CT scans which facilitate fracture classification and the detection of other fractures of the pelvic ring, femoral head, intra-articular fractures and soft-tissue injuries. Other radiographic techniques are available but these are indicated infrequently.

In Chapter 3, the classification of acetabular fractures is discussed. In adults, the classification of Letournel and Judet is preferred, in which a division is made between isolated (and partial) fractures through both columns of the acetabulum or combinations of fractures through one or both columns. Although theoretically an infinite number of fracture patterns is possible, ten different fracture configurations are recognized. The radiographic details of each fracture type are discussed and illustrated. In children, a specific type of fracture is possible which is not included in the Letournel-Judet classification.

This concerns fractures through the physis of the acetabulum: the triradiate cartilage. Three different types of fractures may be identified.

In Chapter 4, the results of both operative and conservative treatment of acetabular fractures in children are described. The overall functional results were better than the radiographic results. Conservative treatment consistently gave good functional and radiographic results in fractures with less than 2 mm displacement and stable posterior fracture-dislocations. In comminuted fractures, the results were less favourable and frequently resulted in some limitation of hip function.

Operative treatment was required in patients with unstable posterior fracture-dislocations and irreducible central fracture- dislocations, in order to obtain reduction of the femoral head. The poor results may be due to extensive heterotopic calcifications, despite anatomical reduction.

The radiographic presentation, treatment and prognosis of triradiate cartilage fractures are discussed in Chapters 4 and 5. Of the three different types, type 1 and 2 triradiate cartilage fractures were easily identified on the initial radiographs. Conservative treatment led to excellent clinical and radiographic results. Type 5 injuries resulted in compression of the physis, which was difficult to recognize on the initial radiographs. Frequently, the diagnosis was missed and remained unclear untill radiographs demonstrated closure of the physis, which is typical for this type of fracture. This resulted in characteristic growth disturbance of the affected hip, which can be recognised between six weeks and one year after the injury. Conservative treatment is preferred for these fractures as operative treatment cannot reconstruct the destroyed physis.

Depending on the severity of the growth disturbance, secondary reconstructive procedures may be necessary.

The results of conservative treatment of acetabular fractures in 57 adults are discussed in Chapter 6. Satisfactory results were achieved in 43 patients. Specific attention was paid to the role of the weight-bearing dome and anatomical reduction in the end results. A method using so-called roof arc measurements was employed to determine the degree of involvement of the weight-bearing dome. In general, good functional results were obtained in fractures in which congruency could be achieved and maintained during the period of traction, even with violation of the weight-bearing dome. The results were almost uniformly poor in patients in whom congruency of the acetabulum could not be obtained, especially in fractures through the weight-bearing dome. Nearly all the poor results were seen in patients with posterior fracture types, T-shaped and high transverse fractures, in which congruency was difficult to achieve.

In Chapter 7, the results of open reduction and internal fixation of acetabular fractures in 54 patients are discussed. The overall functional results were satisfactory in 33 patients. In 36 patients, fracture reduction was congruent. In the majority of these patients, satisfactory functional results could be achieved. If congruency could not be obtained, functional results were uniformly unsatisfactory. The two most important factors related to a poor end result were failure to obtain congruency and heterotopic calcification. Heterotopic calcification was responsible for the poor results in several patients, despite anatomical reduction of the fracture.

CONCLUSIONS

On the basis of this retrospective study, the following conclusions can be drawn.

1. Every child with a pelvic fracture must be kept under clinical and radiographical control for at least one year following the initial injury.
2. The prognosis of type 5 triradiate cartilage injuries is poor, especially if the injury occurred before the age of 10.
3. The involvement of the weight-bearing dome is not the decisive factor in the treatment strategy and prognosis.
4. The primary treatment of central fracture-dislocations and fractures with significant displacement should be conservative with longitudinal (if necessary combined with lateral) traction.
5. If congruency cannot be achieved in this way in posterior type of fractures, transverse, T-shaped and both column fractures with posterior dislocation, open reduction and internal fixation should be considered. The anterior type of fractures have, in general, a much better prognosis and operative treatment is infrequently indicated.
6. Heterotopic calcifications and failure to obtain congruency are the two most important factors related with poor results after open reduction and internal fixation of acetabular fractures.
7. An end-result is not reached two years post-injury as functional and radiographical results may worsen after this period.

Chapter 9

Samenvatting en conclusies

SAMENVATTING

Acetabulumfracturen zijn zeldzaam. Veelal betreft het patienten met meervoudig ernstige, soms levensbedreigende verwondingen. De ernst van deze verwondingen bepaalt de aard en omvang van de eerste hulp aan de patient. Na deze eerste opvang zal een behandelingsplan voor de acetabulumfractuur gemaakt moeten worden. Hierbij kan een keuze gemaakt worden tussen conservatieve en operatieve methoden.

De resultaten van conservatieve behandeling van acetabulum-fracturen door middel van tractie zijn reeds vele tientallen jaren geleden voor het eerst beschreven. Sedert de vijftiger jaren wordt steeds vaker een operatieve behandeling van deze fracturen toegepast, waarbij gestreeft wordt naar een zo optimaal mogelijke repositie van de fractuur, gevolgd door een stabiele interne fixatie. Meerdere nieuwe chirurgische toegangswegen, repositie en fixatiemethoden werden hiervoor beschreven. De techniek van deze chirurgisch niet eenvoudige ingrepen is nu wijdverspreid maar de lange-termijn resultaten en indicaties voor een dergelijke behandeling zijn nog onduidelijk. Ook in de literatuur blijken zeer wisselende resultaten beschreven te worden, zowel van conservatieve als operatieve behandeling. De keuze voor een bepaalde behandeling van een patient met een acetabulumfractuur is dan ook vaak niet eenvoudig.

Om deze keuze toch mogelijk te maken, werden voor dit proefschrift de lange-termijn resultaten en de factoren welke deze resultaten lijken te beinvloeden, retrospectief onderzocht. Over de lange-termijn resultaten en prognose van acetabulumfracturen bij kinderen, in het bijzonder fracturen door de groeischijf van het acetabulum, zijn weinig gegevens bekend. Deze fracturen worden dan ook in aparte hoofdstukken beschreven. De röntgendiagnostiek van acetabulumfracturen wordt beschreven in hoofdstuk 2. Een zorgvuldig uitgevoerde röntgendiagnostiek is een belangrijk onderdeel van het behandelingsplan. Bij iedere patient met een acetabulumfractuur dienen minimaal drie röntgenfoto's te worden vervaardigd: een voor-achterwaartse opname van het bekken en twee aanvullende opnames van de aangedane heup: de zogenaamde ala en obturatoria opnames. Deze drie standaardröntgenfoto's kunnen eventueel aangevuld worden met een computer tomografisch onderzoek van het bekken, waarmee aanvullende informatie verkregen kan worden omtrent begeleidende letsels van de heupkop, het bekken en de weke delen. Om het fractuurtype eenvoudiger te kunnen vaststellen, worden een vijftal 'hulplijnen' beschreven, welke op de röntgenfoto's kunnen worden ingetekend.

De classificatie van acetabulumfracturen wordt beschreven in hoofdstuk 3. Acetabulumfracturen bij volwassenen worden ingedeeld volgens de classificatie van Letournel en Judet, welke onderscheid maakt tussen een tiental verschillende fractuurtypes, uitgaande van één of beide peilers van het acetabulum. Bij kinderen kunnen bovendien een drietal verschillende fractuurtypes van de groeischijf van het acetabulum worden onderscheiden. Dergelijke fracturen worden ingedeeld volgens de classificatie van Salter en Harris. De radiologische kenmerken van alle fractuurtypes worden besproken en met voorbeelden toegelicht. De resultaten van zowel operatieve als conservatieve behandeling van acetabulumfracturen bij een groep van 23 kinderen worden beschreven in hoofdstuk 4. Goede functionele en radiologische resultaten konden bereikt worden na conservatieve behandeling van stabiele achterwand of achterste peiler fracturen en fracturen met minder dan 2 mm. dislocatie. Met stabiliteit wordt hier en in het vervolg bedoeld dat de heup niet luxeert bij 90 graden flexie. Na conservatieve behandeling van communitieve fracturen waren de resultaten minder gunstig, door de optredende bewegingsbeperking van het heupgewricht. Bij vier patienten met een instabiele fractuur van de achterwand of achterste peiler werd bloedige repositie en interne fixatie verricht. Ondanks anatomische repositie, gedefinieerd als 2 mm dislocatie, was het resultaat van deze behandeling bij één patient slecht, ten gevolge van uitgebreide ectopische botvorming.

De röntgendiagnostiek, behandeling en prognose van fracturen door de groeischijf van het acetabulum, het Y-kraakbeen, worden beschreven in de hoofdstukken 4 en 5. De drie verschillende fractuurtypes worden toegelicht aan de hand van voorbeelden. De types 1 en 2 volgens de Salter-Harris classificatie kunnen eenvoudig herkend worden op de ongevalsfoto's. Door conservatieve behandeling kunnen goede resultaten bereikt worden. Bij het type 5 fractuur ontstaat een compressie in de groeischijf, welke moeilijk te herkennen is op de ongevalsfoto's. De diagnose wordt aanvankelijk dan ook vaak miskend en pas gesteld als er op de röntgenfoto's een sluiting van de groeischijf herkend wordt. Deze sluiting van de groeischijf zal in de meeste gevallen een karakteristieke groeistoornis van de aangedane heup tot gevolg hebben, welke zes weken tot één jaar na het ongeval op de röntgenfoto zichtbaar wordt. In eerste instantie wordt een conservatieve behandeling van type 5 fracturen aanbevolen, aangezien operatieve behandeling de beschadigde groeischijf niet kan herstellen. Afhankelijk van de ernst van de optredende groeistoornis, kan in een later stadium operatieve behandeling overwogen worden, met als doel een betere overdekking van de heupkop te verkrijgen.

De resultaten van conservatief behandelde acetabulumfracturen bij 57 volwassen patienten worden vermeld in hoofdstuk 6. Bij het na-onderzoek, verricht na gemiddeld 7.9 jaar, hadden 43 patienten een goed of uitstekend functioneel resultaat, gemeten aan de hand van de Harris-hip score. Tevens werd onderzocht in hoeverre het wel of niet bereiken van anatomische repositie, met name in het 'gewicht-dragende' deel van het acetabulum, de uiteindelijke resultaten kunnen beinvloeden. Een meetmethode wordt beschreven om te kunnen beoordelen of het 'gewicht-dragende' deel door de fractuur beschadigd is. Goede resultaten werden bereikt bij patienten bij wie de fractuur anatomisch gereponeerd kon worden door tractie, zelfs indien het 'gewicht-dragende' deel beschadigd was. Indien geen anatomische repositie bereikt kon worden, resulteerde dit bij alle patienten in een slecht functioneel eindresultaat. Vooral bij achterwand, achterste peiler, T-vormige en hoge dwarse fracturen kon anatomische repositie niet of moeilijk bereikt worden, waardoor dan ook veelvuldig een slecht resultaat optrad.

In hoofdstuk 7 worden de resultaten van bloedige repositie en interne fixatie beschreven. Na gemiddeld 9,6 jaar kon bij 33 van de 54 patienten een goed of uitstekend functioneel resultaat worden vastgesteld. Bij 36 patienten kon anatomische repositie bereikt worden. Het merendeel van deze patienten had een goed of uitstekend functioneel eindresultaat. Indien de repositie niet anatomisch was resulteerde dit altijd in een matig of slecht functioneel resultaat, gemeten aan de Harris-hip score. Niet anatomische repositie en ectopische botvorming bleken de twee belangrijkste factoren te zijn, welke met een slecht functioneel eindresultaat correleerden.

CONCLUSIES EN AANBEVELINGEN

Op basis van deze retrospectieve studie kunnen de volgende conlcusies worden getrokken.

1. Ieder kind met een bekkenfractuur dient klinisch en met behulp van röntgenfoto's gedurende minimaal één jaar na het ongeval gecontroleerd te worden.
2. De prognose van type 5 fracturen door de groeischijf van het acetabulum is slecht, in het bijzonder indien het letsel voor het tiende levensjaar optreedt.
3. Beschadiging door een fractuur van het 'gewicht-dragende' deel van het acetabulum is niet van doorslaggevend belang bij de behandelingskeuze en prognose.
4. Centrale luxatie-fracturen en fracturen met aanzienlijke dislocatie kunnen in eerste instantie conservatief behandeld worden door middel van lengte (eventueel gecombineerd met zijwaartse) tractie.

5. Indien door tractie geen anatomische repositie bereikt kan worden bij dwarse, T-vormige en beide peiler fracturen met posterior luxatie, dient bloedige repositie en interne fixatie overwogen te worden. Fracturen van de voorwand en voorste peiler hebben over het algemeen een betere prognose en operatieve behandeling is zelden geindiceerd.
6. Ectopische botvorming en onvoldoende repositie van de fractuur zijn de belangrijkste oorzaken van slechte resultaten na bloedige repositie en interne fixatie van acetabulum- fracturen.
7. Het "eind-resultaat" is twee jaar na het ongeval nog niet bereikt, aangezien zowel de functionele als radiologische resultaten nog kunnen verslechteren na deze periode.

Curriculum vitae

Minne Heeg was born on the 14th of September, 1959 in Itens (Friesland), The Netherlands. After graduation from the Magister Alvinus high school/ college in Sneek in 1977, he attended medical school at the University of Gent in Belgium. From 1978 to 1985 he studied at the medical school of the University of Groningen.

In 1983 he spent five months in Japan, where he worked at the Department of Cardiovascular Surgery of the University of Kyoto (Dr. H. Fukumasu) and the Department of Neurosurgery of the University of Tokyo (Prof. Dr. K. Sano).

After completing his medical studies, he was a house officer in the Department of Orthopaedic Surgery of the University Hospital in Groningen, from January to August 1986. His residency in general surgery was fulfilled in the Roman Catholic Hospital of Groningen (Head: Dr. L.J.M. Vos).

In September 1988 he started his training in Orthopaedic Surgery at the Department of Orthopaedic Surgery of the University Hospital in Groningen, under the direction of Prof. Dr. H.K.L. Nielsen.